THE FAUNA OF THE PORTRANE LIMESTONE, II

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By A. D. WRIGHT

CONTENTS

SYNOPSIS

This paper is the second of a series by several authors on the Portrane Limestone fauna, and is concerned with the articulate brachiopods of the "*Orthis*" group, comprising the superfamilies Orthacea, Dalmanellacea, Clitambonitacea and Triplesiacea. Thirty-five species belonging to thirty genera are described, including the new family Saukrodictyidae ; three new genera, *Portranella, Spinorthis* and *Saukrodictya*; sixteen new species and three new subspecies.

I SYSTEMATIC DESCRIPTIONS

Superfamily **ORTHACEA** Woodward 1852

Family **ORTHIDAE** Woodward 1852

Subfamily **ORTHINAE** Woodward 1852

Genus ***ORTHAMBONITES*** Pander 1830

Orthambonites humilidorsatus sp. nov.

(Pl. 1, figs. 1–12)

Diagnosis. Ventri-biconvex valves of subquadrate outline ; ventral valves averaging six-sevenths as long as wide and just over one-third as deep as long, evenly and fairly strongly convex in lateral and anterior profile, with curved apsacline interarea less than one-tenth of valve length. Hinge-line about four-fifths of maximum valve width. Cardinal angles obtuse, usually prominent. Dorsal valve flatly convex, less than one-fifth as deep as long ; lateral profile gently and evenly convex, anterior profile depressed medianly by a slight but invariably present sulcus, which produces a gently sulcate anterior commissure. Ornamentation of angular costae only, commonly numbering 15 on ventral valve, range 14–16, and range of 14–17 on dorsal valve where the median pair occupy the sulcus. Mean wavelength of costae about 0·75 mm. at 5 mm. anteromedian to the ventral umbo.

Ventral interior with short stout teeth supported by receding dental plates; muscle field about two-thirds as wide as long and almost two-fifths as long as valve; submedian diductor lobes extending beyond adductor scars, the latter situated on a

variably developed thickening which increases towards the front of the scar, often becoming prominent anterior to the scar where it forms a low ridge extending to about mid-valve.

Dorsal interior with sockets bounded by short blade-like brachiophores, supported posteriorly by secondary shell substance. Cardinal process passing into notothyrial platform anteriorly ; posteriorly it rises steadily from the platform partially to fill and project from the notothyrium. The process always becomes narrower posteriorly, but may vary in width from very slender to broad in different specimens. Ventral surface of process smooth, diductor muscles being attached posteriorly to its dorso-lateral surfaces on either side of median eminence. Anterior to notothyrial platform the poorly defined subquadrate adductor field is divided longitudinally by low median ridge.

		Maximum length	*Width*
Holotype.	Ventral valve (BB.30150) .	7·5 mm.	8·3 mm.
Paratypes.	Ventral valve (BB.30151) .	6·2 mm.	7·0 mm.
	Complete shell (BB.30152) .	7·8 mm.	10·2 mm.
	Incomplete dorsal valve (BB.30153) .	6·0 mm.	c. 7 mm.
	Dorsal fragment (BB.30154) . . .	5·7 mm.	—
	Incomplete ventral valve (BB.30155) .	7·9 mm.	c. 8 mm.
	Ventral fragment (BB.30156) . .	—	c. 9 mm.

Discussion. The Portrane specimens of *Orthambonites* show their closest morphological similarity to two forms, *O. playfairi* and *O. lyckholmiensis*. A new species recently erected by Williams (1963: 350) from the Gelli-grîn Group at Bala, *O. cessata*, is also similar in the style of its ornamentation, having about 15 subangular costae, which compares closely with the distribution of 14–16 costae on 3, 13, 5 Portrane ventral valves. The wavelength of the ribs, measured medianly at 5 mm. anterior to the umbo, in three specimens of *O. cessata* is 0·5, 0·5 and 0·7 mm.; the figures for 10 Portrane valves are 0·6, 0·6, 0·65, 0·7, 0·75, 0·75, 0·85, 0·9, 0·9, 0·9 mm. A Rank Sum Test indicates that the ribs of the Welsh form are significantly narrower than those of the Irish one, $P = 0{\cdot}038$. While there is no significant difference in the relative thickness of the ventral valves of the two forms, three Bala dorsal valves have ratios of 23, 24, 25% for the thickness : length of the dorsal valves, compared with 15 and 17% for two Portrane valves. The Portrane dorsal valves, then, are shallower and also possess a clearly marked dorsal sulcus, which is obscure in *O. cessata*. The high interarea of *O. cessata* further separates the two forms.

Reed (1917 : 829) erected the species *O. playfairi* for specimens from several horizons in the Girvan area. Recently Williams (1962 : 97) has re-described this form, and in so doing has restricted *O. playfairi* to the forms from Craighead. The Scottish shells have a similar number of ribs to the Portrane shells ; their wavelength, taken 5 mm. anteromedianly to the dorsal umbo, is 0·87 mm. (var. 0·004) in a sample of 14 valves, which shows no significant difference from the 0·81 mm. (var. 0·092) recorded for 5 Portrane valves.

Williams (1962 : 97) states that the ventral valve of *O. playfairi* is " less than one third as deep as long ", his sample of 33 specimens having a mean of 31·8% (var.

18·0) for this character. A sample of 10 Portrane valves has a mean of 36·2% (var. 19·06) ; on testing, the latter proves to be significantly deeper (·01 > P > ·001). Although the outline of the average Portrane ventral valve tends to be more transverse than the Craighead shells, tests comparing the a's and b's show that the difference is not significant.

The length of the ventral muscle field : length of ventral valve is given as less than two-fifths for *O. playfairi* ; 37 and 39% for two Portrane valves compare closely with this figure. Due to the faint nature of the impressions, no data are available on the dimensions of the dorsal muscle field of the Portrane species.

From Williams' original data the width of the interarea : maximum valve width was calculated for 4 valves, the figures being 60, 62, 71, 79%. The figures for this character in 7 Portrane valves are 75, 76, 78, 78, 80, 80, 85% and a comparison by Rank Sum Test shows the Portrane shells to have a significantly wider hinge-line (P = 0·036).

A further difference between the two forms appears to exist in the relative lengths of the ventral interareas, which are very short in the Portrane specimens. In 5 of these valves, the length of the interarea: valve length is 7·5, 7·6, 8·7, 9·3, 9·5%, with a mean of 8·5% (var. 0·86). Unfortunately, Williams does not include data for this feature, but his figured specimen (pl. 7, fig. 41) at least has a better developed interarea than any of the Irish specimens, the length being over 10% of the valve length.

Reed figured three specimens from the Whitehouse Beds (1917 : pl. 5, figs. 30–32) ; in his description (p. 831) he stated that these are especially comparable to *O. lyckholmiensis*. Apart from Reed's fig. 31 of a ventral valve, which has a hinge-line somewhat wider than those of the Portrane sample and also 17 costae, the other characters that can be ascertained from these three figures are not inconsistent with the data for the Portrane valves, and on the relative lengths of the hinge lines are certainly closer to the Portrane valves than to the *O. playfairi* from Craighead. It will, however, be necessary to obtain a sample of the Whitehouse specimens in order to clarify their exact relationships with the Portrane valves.

O. lyckholmiensis was erected by Wysogorski (1900 : 231) for forms from the " Lyckholm Stratum " of Estonia ; according to Jaanusson (1944 : 96), the well known and richly fossiliferous Lyckholm *sensu stricto* occurs in the Lower (Kõrgessare) zone of the Vormsi (F_{1b}) stage.

From Wysogorski's figure (pl. 8) it may be noted that the dorsal valve is about a quarter, and the ventral about a third, as deep as long. The Estonian forms have recently been re-described by Oraspöld (1959 : 57), who describes the ventral valves as being moderately convex, and the dorsal valves as weakly convex with a flat sulcus. His table of dimensions (p. 58) only gives the thickness of complete shells, but his lateral view of a shell (pl. 2, fig. 2*a*) shows the dorsal valve to be about 30%, and the ventral valve to be about 36%, of their respective lengths. This confirms the evidence of Wysogorski's figure ; thus, whilst the depth of the ventral valves of the Estonian and Portrane shells is very similar, the former possess much deeper dorsal valves.

A comparison of the length : width ratios obtained from Oraspöld's table with those of the Portrane valves shows no significant difference ; in the ribbing, outline, hinge-length and ventral interior the two forms are also closely comparable. In the dorsal interior, although there is a tendency for the rather blade-like brachiophores to become thickened in the Portrane shells as in the Estonian forms, differences can be seen in the cardinal process. Oraspöld described that of *O. lyckholmiensis* as being " thick, and in the posterior part, wedge-shaped ". His figure (pl. 2, fig. 4) confirms this. Although some of the cardinal processes of the Portrane shells are quite broad, the majority are slender ; but even the broad ones show a posterior tapering to the process, in contrast to those of the Estonian valves.

Wiman (1907 : 8) ascribed specimens from the Leptaena Limestones of Dalarne, Sweden, to Wysogorski's species ; his figures (pl. 2, figs. 9–12) show a much closer resemblance to the Portrane valves than to the Estonian form ; for, apart from having characters common to both, the thickness of the dorsal valve (fig. 10) is comparable to that of *O. humilidorsatus* (being about 18% of the valve length) ; the cardinal process is slender and, more important, tapers posteriorly ; the brachiophores are slender ; the delthyrium is wide and the interarea very short ; all these features indicate the closer affinity of Wiman's shells to those from Portrane rather than the Estonian forms.

In conclusion, the new species is very close to the Estonian *O. lyckholmiensis*, but may be distinguished from that species by the much shallower dorsal valve and the features of the dorsal cardinalia. The species identified by Wiman from the Leptaena Limestone appears to be conspecific with *O. humilidorsatus* ; whilst the forms from the Girvan Whitehouse Beds attributed to *O. playfairi* by Reed may also belong to this species.

Genus ***TAPHRORTHIS*** Cooper 1956

Taphrorthis ? sp.

(Pl. 1, figs. 13–20)

Description. Shallowly biconvex valves of transversely subquadrate outline ; growth lines on a dorsal valve show the length to be just over half of the width in very early growth stages, this ratio increasing with increased growth of the valve. Posterolateral margins straight, narrowing or widening anteriorly, so that the width of the hinge-line is variable, but usually about equivalent to the maximum valve width. Dorsal valve between one-sixth and one-eighth as deep as long ; lateral profile gently convex with maximum convexity umbonally ; anterior profile depressed medianly by a variably developed sulcus which dies out anteriorly. Interarea flat, anacline, about one-ninth of the valve length ; notothyrium open. Ventral valve somewhat deeper, with greatest depth umbonally ; short apsacline interarea, delthyrium modified by lateral plates ; no fold corresponding to the dorsal sulcus, although the median rib is prominent posteriorly. Ornamentation of well-defined concentric fila (about 4 per mm.) imposed on radial costae and costellae ; about 26 ribs developed at the beak, only a few of which appear to be secondary, having arisen from costae within a mm. of the apex ; only sporadic costellae produced

until between 7 and 10 mm., when a generation appear, with a further generation developed later.

Ventral interior with teeth supported by receding dental plates ; broad, rather short, bilobed muscle field, with diductors extending beyond and not enclosing the adductor scars. Dorsal interior with simple ridge-like cardinal process on a variably thickened notothyrial platform which extends anteriorly to about mid-valve as a low ridge ; brachiophores short, slender and pointed distally, with bases convergent on to the notothyrial platform.

Material	Length	Width
Dorsal fragment (BB.30157) . . .	14·2 mm.	—
Dorsal valve (BB.30158)	14·6 mm.	c. 18 mm.
Ventral fragments BB. 30159-61 . .		

Discussion. The fragmentary nature of the small quantity of material available is reflected in the shortage of data. The numbers of ribs at 2 and 3 mm. from the dorsal umbo in two valves are 26 in each case ; a third shows 13 and 16 at these respective distances developed on half the valve. Half-valve measurements at 5 and 10 mm. for two valves are 18, 19 and 28, 31 at the respective distances. At 5 mm. from the dorsal umbo, 2 valves showed 4 ribs per 2 mm.

The closest of the other Portrane shells to this species is *Dolerorthis inaequicostata* (p. 190), but the species provisionally assigned to *Taphrorthis* may be clearly distinguished by the large number of ribs developed at the umbo, the less regular pattern of costellae development, the flatter valves and impersistent nature of the dorsal sulcus, and by the dorsal cardinalia where the brachiophores are quite different from the blade-like ones of *Dolerorthis* which are further grooved on the inside surface and have rounded extremities.

The shells show a strong resemblance to *Taphrorthis*, and conform to Cooper's description of that genus (1956 : 326) in all features except the five generations of costellae, the linear nature of the ventral diductor scars and the median ridge dividing the adductor field which extends " as far as the middle " (of the valve). The type species, *T. emarginata*, possesses a sulcus in the dorsal valve which persists to the anterior margin ; but in Cooper's other species, *T. peculiaris*, the sulcus becomes obsolete at the front of the shell as in the Portrane form.

Of the costae developed at the beak, a few branch very close to the beak ; these costellae would correspond to Cooper's second generation. Prior to the main costellae development that takes place between 7 and 10 mm., only a few sporadic costellae develop ; these may correspond to Cooper's third generation, although one hesitates to apply that term to such a sparse development. The main costellae development may certainly be termed a generation ; rather less prolific is a later generation, which was observed on only one valve.

The ventral diductor scars seen in the Portrane fragments could hardly be termed " linear ", but this would seem to be a rather variable character in the genus (cf. Williams 1962 : pl. 8, fig. 34). A more important difference is the absence of the ridge which divides the ventral adductor scar and extends to the middle of the valve in *Taphrorthis*. This ridge is not apparent in Cooper's figure of *T. peculiaris* (1956,

pl. 38, fig. 18), although it is certainly present in the Scottish stocks described by Williams, sometimes approaching *Glossorthis* in the development of a pseudospondylium (1962 : 104).

In view of the absence of this ridge in the Portrane ventral valve, and the small and fragmentary nature of the sample, the forms are here placed provisionally as *Taphrorthis* ? sp.

Subfamily ***PRODUCTORTHINAE*** Schuchert & Cooper 1931

Genus ***NICOLELLA*** Reed 1917

Nicolella actoniae (J. de C. Sowerby)

(Pl. 2, figs. 1–7, 10, 11)

1839 *Orthis actoniae* J. de C. Sowerby *in* Murchison : 639, pl. 20, fig. 16.
1846 *Orthis actoniae* Sowerby ; M'Coy : 28.
1853 *Orthis actoniae* Sowerby ; Medlicott : 268.

Description. Plano- to gently concavoconvex valves of subquadrate outline ; cardinal extremities acute, mucronate. Ventral valves strongly convex, about one-third as deep as long and four-fifths as long as wide, with the transverse, deep shells of young adults becoming elongate and relatively less deep with increased size. Maximum width normally at the hinge-line, but in older shells the width at mid-valve occasionally becomes slightly greater. Interarea short, curved orthocline to anacline ; delthyrium open. Protegulum of dorsal valve convex, the valve quickly becoming gently concave, with length averaging two-thirds of the valve width ; interarea short, flat, slightly hypercline ; notothyrium filled by cardinal process and chilidial plates. Concentric ornament of sporadically developed lamellose growth lines ; radial ornament of 10 to 12 angular initial costae (most commonly 10) on the dorsal valve, with additional costae appearing along the hinge-line to produce between 11 and 16 (most commonly 12) by the 7·5 mm. growth stage ; about half the sample develop costellae (internal) by this stage, with 4a⁻ usually appearing first. Wavelength of ribs just over one mm. at the 5 mm. growth stage.

Ventral interior with teeth supported by short dental lamellae ; pedicle callist well developed, otherwise muscle field and pallial markings poorly preserved. Dorsal interior with high simple cardinal process flanked by chilidial plates ; brachiophores widely divergent, the distance between their distal extremities being about one-quarter of the valve width ; notothyrial platform continued anteriorly as a low median ridge reaching the front of the subquadrate adductor scars.

Figured Specimens	Length	Width
Complete shell, slightly broken anteriorly (BB.30162)	—	c. 20 mm.
Ventral valve, broken anteriorly (BB.30163)	—	c. 20 mm.
Deformed dorsal valve (BB.30164)	—	c. 23 mm.
Broken dorsal valve (BB.30165)	—	—
Ventral fragment (BB.30166)	—	—

Discussion. In order to swell the statistical data, the amount of which was not very large due to the partly broken nature of the larger shells in particular, use has been made of well-marked growth stages, for these do register the true shape of the valve during development (Wright, 1960 : 260).

A re-description of *Nicolella actoniae* has recently been given by Williams (1963 : 352), based on material obtained from the Actonian Stage of the Caradocian at Acton Scott, Shropshire. In the same paper he erected a new subspecies, *N. actoniae obesa*, for the earlier form from the Gelli-grîn Beds at Bala. This differs from *N. actoniae* in its smaller size and in possessing relatively deeper ventral valves.

A consideration of the depth of the ventral valves indicates that the growth of the Portrane shells is allometric, a feature not evident in either of Williams' samples ; the data for the Portrane shells, with full data for Williams' samples, are given in Table 1. A comparison of the Portrane material with the Bala and Acton Scott samples shows that it is not distinguishable from either, there being no significant difference in the values of α or β. The Portrane ventral valves vary in length from about 2 mm. to almost 26 mm. ; so that in absolute size they are closer to the Acton Scott form, rather than the Bala form.

The following data were obtained for the length (l) : width (w) of a sample of 9 dorsal valves from Portrane :—$\bar{l}$ (var. l) = 8·85 mm. (10·21) ; $\bar{w}$ (var. w) = 13·15 mm. (21·96) ; r = 0·9638 ; a (var. a) = 1·467 (0·02185) ; $\overline{\log_e l}$ (var. $\log_e$ l) = 2·1191 (0·1226) ; $\overline{\log_e w}$ (var. $\log_e$ w) = 2·5167 (0·1193) ; r_e = 0·9661 ; α (var. α) = 0·9863 (0·000986). Tests for allometry proved negative, but allometric data are included above in order to make comparisons with the figures given by Williams (1963 : 355) for *N. actoniae*, whose larger sample reveals allometric effects. The comparisons of the α's and β's reveal that the differences between the two forms are not significant at the 5% level.

No figures were given by Williams for the length : width of the ventral valve. A sample of 12 Portrane valves produced the following data :—$\bar{l}$ (var. l) = 10·0 mm. (50·1) ; $\bar{w}$ (var. w) = 12·05 mm. (38·0) ; r = 0·9317 ; $\overline{\log_e l}$ (var. $\log_e$ l) = 2·0996 (0·4060) ; $\overline{\log_e w}$ (var. $\log_e$ w) = 2·3727 (0·2325) ; r_e = 0·9462 ; α (var. α) = 0·7567 (0·007553).

Data on the ventral muscle scars of the Portrane shells are sparse, due to the very light nature of the impressions. Accordingly, width : length ratios were obtained for two valves only, these figures (83%, 88%) being comparable to the mean (c. 90%) of the Acton Scott forms.

Only one specimen shows the ratio of length of scar ; valve length (32·5%). One of Williams' 12 specimens has a ratio of 31%, but the mean is much higher (c. 41%). Thus the muscle scar may be shorter relative to valve length in the Portrane shells, but no definite conclusion can be derived from the evidence of this solitary valve.

Measurements show the ratio of the width of the brachiophores to the valve width in four shells to be 19, 22, 24, 29% ; no figures were given by Williams for this character.

In the ornamentation, the wavelength of the ribs measured 5 mm. anterior to the umbo in 21 dorsal valves is 1·16 mm. (var. 0·0198) ; a " t " test shows this to be significantly larger (·05 > P > ·02) than the figure given by Williams for the Acton Scott forms (1·05 mm., var. 0·023 for 15 valves). Like these shells, the pattern of the Portrane dorsal valves consists basically of 5 costae on either side of the median plane, occupying a sector of about 125°, with other costae developed later in the posterolateral regions, so that a count at the 7·5 mm. growth stage shows 11–16 primaries on 2, 5, 0, 1, 1, 1, valves. Within this growth stage, 10 out of 21 dorsal valves developed secondary costellae branching internally from one or more costae, with 4a⁻ usually the first to develop ; in a sample of 9 valves it arises first in 6, and second in the other 3 valves ; 1a⁻ arises before 3a⁻ in 3 out of 5 specimens. Thus the Portrane shells tend to have fewer costae and more costellae developed in the early stages than in the Acton Scott shells, but 2 × 2 contingency tests reveal that the differences in these samples, and in the sample from Bala, are not significant at the 5% level.

The only significant difference established between the Portrane sample and the Acton Scott sample is that of the rib wavelength ; but the actual difference is so small that it does not seem to justify even a subspecific difference, and so the shells are accordingly placed as *Nicolella actoniae* s.s.

The *N. actoniae* stock thus appears to have been fairly stable over a considerable period of time. In the Girvan area, it is interesting to note that Reed (1917 : 860) said that this species is only known with certainty from the Whitehouse Beds at Shalloch Mill ; the forms from the later Drummuck Beds and earlier Craighead Limestones (see Williams 1962 : 104) are quite distinct.

TABLE 1

	A.	B.	C.
n	15	22	15
$\bar{l}$ mm. (var. l)	10·51 (47·8)	15·11 (20·912)	8·95 (11·804)
$\bar{t}$ mm. (var. t)	3·81 (4·63)	4·61 (1·928)	3·71 (2·566)
r	0·9766	0·9877	0·8433
$\overline{\log_e l}$ (var. $\log_e$ l)	2·1726 (0·3596)	2·6713 (0·0881)	2·1231 (0·1371)
$\overline{\log_e t}$ (var. $\log_e$ t)	1·1993 (0·2767)	1·4846 (0·0872)	1·2252 (0·1716)
r_e	0·9817	0·9766	0·8364
α (var. α)	0·8772 (0·002735)	0·9949 (0·00225)	1·119 (0·0290)

TABLE 1. Statistics of length (l) and maximum thickness (t) of ventral valves of *Nicolella actoniae* (J. de C. Sowerby) obtained from Portrane (A) and Acton Scott (B), and of *N. actoniae obesa* Williams from Bala (C).

Family **ORTHIDIELLIDAE** Ulrich & Cooper 1936

Genus ***PORTRANELLA*** nov.

DIAGNOSIS. Ventri-biconvex shells of sub-elliptical outline, hinge-line less than maximum valve width ; ventral valve with maximum convexity close to incurved beak. Interarea short, curved, apsacline ; delthyrium open. Dorsal valve with median sulcus ; interarea very short, anacline ; notothyrium filled by cardinal

process. Ornamentation of strong, angular costae and costellae. Shell substance impunctate?

Ventral interior with short teeth showing crural fossettes, supported by thick dental plates ; muscle field sub-oval, pedicle callist thick. Dorsal interior with short, stout brachiophores whose bases diverge ; fulcral plates absent. Shaft of cardinal process obsolete ; myophore trilobed, situated posteriorly to brachiophores, with lateral lobes extending over posterior surface of brachiophores ; thickening of valve floor between brachiophores passing into low rounded ridge extending to almost mid-valve.

Discussion. Although the individual structures found in *Portranella* show strong similarities to those of several impunctate and punctate stocks, the assemblage of characters is quite distinct from that of any other described brachiopod.

With regard to the shell substance, one ventral valve shows a series of dark spots on some costae when the surface is moistened ; but it seems very doubtful if these are traces of endopunctation. No other suggestion of it was observed in the other specimens. The failure to detect punctation is unfortunately not conclusive ; for although the punctate nature of the shell can be seen in very finely silicified material, its absence may be due either to the shell being impunctate originally or to the obliteration of the puncta during the replacement of the shell substance by the silica.

Trilobed cardinal processes are found in both the Orthacea and Dalmanellacea, although lobate processes in general are more common in the latter. Among the Orthacea, this type of cardinal process is chiefly restricted to the Orthidiellidae ; however, *Schizoramma* is potentially trilobed and is commented on here as its external ornamentation has a similar aspect to that of *Portranella*. The cardinal process of *Schizoramma* is a simple ridge, but on the notothyrial platform on either side is an accessory ridge (Schuchert & Cooper 1932 : 88, pl. 5, fig. 14) ; a posterior rotation of these structures would produce a cardinal process simulating that of *Portranella*. The reverse process of a simplification of the *Portranella* type to the *Schizoramma* type is more difficult to envisage ; but this is what would have to take place if the later (Silurian) *Schizoramma* was evolved from *Portranella*.

A consideration of the cardinalia in particular, shows that there is a much stronger case for the present placing of the genus within the Orthidiellidae, than in any other orthaceid and dalmanellaceid stock. The Orthidiellidae have so far only been recorded in the Lower Ordovician rocks of North America, although Wang (1955 : 336) erected a genus, *Eosotrematorthis*, from the Lower Ordovician of China which he considered to be close to the orthidiellid *Trematorthis*, whilst another of Wang's genera, *Lepidorthis*, was tentatively placed in the Orthidiellidae by Alichova (1960 : 186), although it is probably congeneric with *Glyptorthis* and quite remote from the orthidiellids.

The American genera *Trematorthis*, *Orthidiella* and *Orthidium* all possess triangular trilobate myophores, sometimes with accelerated growth of the median lobe (as in *Orthidiella*) to stimulate a simple cardinal process, and which was in fact regarded as such in Ulrich & Cooper's definition of the family (1938 : 107), although they described *Trematorthis* as having a trilobed cardinal process (p. 112). The important

feature of the cardinal process in the orthidiellids is that it is fused or united to the brachiophores by shell substance (Ulrich & Cooper 1936 : 621). In *Portranella* it is this fusion that, in the absence of definite evidence on the shell structure, suggests a close relation to the Orthidiellidae rather than to those dalmanellids which possess trilobed myophores, e.g. *Resserella elegantula* Dalman, and especially also the *Paucicrura* with a high median lobe as in *Orthidiella* (the *Cristiferina* of Cooper 1956 : 961, see Williams & Wright 1963 : 29) ; for in these dalmanellids the cardinal process is sharply demarcated from the brachiophores by the longitudinal grooves forming the continuation of the notothyrial margins.

From the specimens of *Orthidiella* examined by the writer, and from figured posterior views of the dorsal valve of that genus (Ulrich & Cooper 1938, pl. 17, fig. 32 ; Cooper 1956, pl. 30, fig. 29) and also of *Orthidium* (Ulrich & Cooper 1938, pl. 16, fig. 29), there appears to be no overstepping of the notothyrial margins on to the brachiophores by the lateral cardinal process lobes as in *Portranella*. A tendency for this to occur is, however, seen in *Trematorthis masoni* (see Cooper 1956, pl. 29, fig. 12).

This strong lateral growth of the cardinal process over the brachiophores is a distinctive character in *Portranella* ; the genus may be further differentiated from the other Orthidiellidae by its much coarser, angular ribbing, its shorter hinge and more oval outline ; from *Orthidiella* and *Trematorthis* by the open delthyrium ; and from *Orthidium* by the lack of imbricate ornamentation.

Type species. *Portranella angulocostellata* sp. nov.

Portranella angulocostellata gen. et sp. nov.
(Pl. 2, figs. 12, 13, 15–19, 21, 22)

Diagnosis. Sub-rounded to transversely elliptical ventri-biconvex shells ; length to width of ventral valves ranging from about 70% to 90%, dorsal valve relatively shorter ; hinge-line about two-thirds width of valve. Ventral valve about one-third as deep as long, with short, curved apsacline interarea between one-seventh and one-ninth of valve length. Lateral profile shows maximum convexity near beak, which is moderately incurved ; anterior profile convex, slightly arched medianly. Dorsal valve shallowly convex with median sulcus, deep posteriorly, shallowing towards anterior margin. Interarea very short, anacline, with cardinal process projecting out of notothyrium. Concentric ornamentation normally subdued ; radial ornament of strong angular costae and costellae. Dorsal valve typically with 12 primary costae, median pair usually arising slightly late ; by the 3 mm. growth stage generally 4 ribs in the sulcus and 6 or 7 on each flank. Branching takes place early in sector 4, normally with $4a^{\circ})4a^{-}$, and $4a^{-})3a^{-}$; density of ribs 3 or 4 per 2 mm. medianly at the 5 mm. growth stage.

Ventral interior with short teeth exhibiting variably, but usually well-developed, crural fossettes, and stout dental lamellae ; these do not, however, continue anteriorly as ridges on floor of valve, thus the sub-oval muscle field is poorly defined. Well defined pedicle callist situated apically ; a low ridge is seen to extend anteriorly from front of muscle scar in a single specimen.

Dorsal interior with short stout brachiophores whose bases diverge to bound the sockets ; valve floor between brachiophores thickened and rising posteriorly to myophore ; traces of a median longitudinal ridge (shaft) on this thickening in some specimens. Myophore trilobed, situated perpendicular to plane of valves and posterior to brachiophores ; lateral lobes extend over posterior surface of brachiophores ; median lobe may or may not be stronger than lateral lobes, and may be grooved medianly. Low rounded median ridge rising anterior to cardinalia and extending to about mid-valve.

		Length	Width
Holotype.	Dorsal valve (BB.30167) .	6·4 mm.	9·9 mm.
Paratypes.	Ventral valve (BB.30168) .	5·8 mm.	c. 8 mm.
	Ventral valve (BB.30169) .	6·7 mm.	—
	Broken dorsal valve (BB.30170) . .	—	11·2 mm.
	Damaged dorsal valve (BB.30171) . .	10·3 mm.	c. 12 mm.

Discussion. The angular ribs of this species are coarse (3, 4 ribs per 2 mm. at the 5 mm. growth stage being recorded in 3, 3 valves respectively) and in pattern show similarities to *Schizoramma* or a very coarsely ornamented dalmanellid such as *Dalmanella unguis* (J. de C. Sowerby). Unfortunately, most of the dorsal valves available for rib counts are abraded umbonally, so that the naming of the ribs in the style of Bancroft (Bancroft 1928 ; 1945 : 186 ; Williams 1949 : 163) is rather hazardous. In four shells where the rib origins could be determined with certainty the following relations for the principal costellae are obtained :

Relation	Frequency
$4a^{\circ}) 4a^{-}$	4/4
$4a^{-}) 3a^{-}$	3/3 (1)

One large dorsal valve shows a fascicle of six ribs in sector 2, four of which are internal and one external ; this appears to be exceptional.

The following rather meagre statistical data are included for comparison with other species.

1. Rib counts. (a) in the dorsal sulcus at the 3 mm. growth stage :— 2, 4, 4, 4, 4, 4, 5 ; and at the 5 mm. growth stage :— 4, 5, 5, 6, 6.
   (b) on the flanks at the 3 mm. stage :— 6, 6, 6, 7, 7, 7, 7, 8 ; and at 5 mm. :— 6, 7, 8, 9, 9.
   (c) Total ribs on the ventral valve at 3 mm. from the umbo in three valves is 16, 17, 18 ; and 17, 18, 20 at 5 mm. distance.

2. Thickness of the ventral valve in three specimens is 32, 33 and 39% of the valve length.

3. Length of the dorsal valve in three specimens is 64, 66 and 75% of the valve width.

Family **HESPERORTHIDAE** Schuchert & Cooper 1931

Subfamily **HESPERORTHINAE** Schuchert & Cooper 1931

Genus ***HESPERORTHIS*** Schuchert & Cooper 1931

Hesperorthis sp.

(Pl. 2, figs. 8, 9, 14, 20)

Description. Large plano-convex shells with length and width of ventral valve about equal ; cardinal angles slightly obtuse, posterolateral margins gently rounded, anterolateral and anterior margins fairly strongly rounded. Ventral valve strongly convex, about one-third as deep as long, with greatest depth at mid-valve or slightly posterior to it. Interarea curved, moderately apsacline, between one-quarter and one-third as long as the valve. Dorsal valve flat, with a concavity in neanic stages ; interarea flat, anacline, about one-sixth as long as the valve. Ornamentation of rounded costae, 19, 22 and 27 being recorded for three ventral valves ; interspaces also rounded, with strong lamellose concentric growth lines, 5 per mm., well displayed. Dorsal interior with long, blade-like brachiophores, grooved on the inside and unsupported except by the notothyrial platform ; cardinal process simple. A low rounded ridge extends anteriorly from the notothyrial platform.

Figured Specimens	Length	Width
Ventral valve (BB.30172) . . .	21·2 mm.	—
Dorsal valve (BB.30173)	15·4 mm.	23·9 mm.

Discussion. Four complete valves and several fragments of a *Hesperorthis* are here included as *Hesperorthis* sp. In the case of the ventral valves, the features of the interior and delthyrium are obliterated, whilst the dorsal valves show the features of the interior fairly well, but are caked with silica externally. However, these shells show the typical features of the genus in the cardinalia and flat nature of the dorsal valve, and in the deep ventral valve with its long interarea and costate ornamentation.

The ribbing of the figured ventral valve is of the same density as *Plectorthis* sp. (p. 197), but this form has flat, not curved, rib interspaces, a shorter hinge-line and a more oval commissural outline.

In its sub-equal ventral length, width and ornamentation the Portrane *Hesperorthis* resembles the Silurian *H. davidsoni* (Verneuil) figured by Schuchert & Cooper (1932, pl. 4, fig. 23) ; unfortunately the evidence of the Portrane valves is insufficient for close specific comparisons to be made with other forms. It may indeed be that the specimen with 27 ribs, whose maximum depth is also posterior to that of the other two shells, is a different species or subspecies, but the significance of this sort of variation cannot be judged with confidence from the material available.

Cooper (1956 : 141) remarked that *Hesperorthis* is rare in European faunas. This is certainly true, for the more recent fossil lists show it to be absent from the Caradocian of the Bala district (Williams 1963 : 335), South Shropshire (Dean 1958 :

218) and Cross Fell (Dean 1959 : 208), and from the Lower Ashgillian at Cautley (King & Williams 1948 : 210).

Of the Girvan fauna described by Reed (1917 : 827), only his subspecies *Orthis calligramma craigensis* is referable to this genus. Williams (1962 : 107) has recorded a new subspecies from the *confinis* Flags, but Lamont's lists (1935 : 299) for the Drummuck Beds show nothing which might be referable to *Hesperorthis*. Neither do those of King (1932 : 104) for the Horton Limestone, nor of Whittington (1938*a* : 451) for the Ashgillian of Llansantffraid.

For other areas of Upper Ordovician rocks there are records of the species *Orthis calligramma*, for example from the Kildare and Keisley Limestones (Reynolds & Gardiner 1896 : 593, Reed 1897*a* : 68). This species is, however, something of a form species, and some of the specimens ascribed to it may prove to belong to *Hesperorthis*. Those included in this species from Portrane by Baily (1861 : 11) include a plectorthid and two other " orthid " fragments, but which are certainly not conspecific with *O. calligramma* as figured by Dalman (1828, pl. 2, fig. 3 *a-d*).

Subfamily **GLYPTORTHINAE** Schuchert & Cooper 1931

Genus ***GLYPTORTHIS*** Foerste 1914

Glyptorthis maritima sp. nov.

(Pl. 1, figs. 21–29)

Diagnosis. Subelliptical to subquadrate ventri-biconvex *Glyptorthis*. Ventral valve about five-sixths as long as wide, and about one-third as deep as long ; maximum shell width anterior to hinge-line, cardinal angles somewhat greater than 90°. Lateral profile gently convex, convexity increasing anteriorly in older shells ; anterior profile evenly convex to sub-carinate. Interarea gently curved, apsacline, about one-fifth as long as wide and one-fifth as long as ventral valve. Young stages with fold formed by high median rib (branching to produce a fascicle of 3 or sometimes 5 ribs) which becomes lost in adult life when it is replaced by a shallow sulcus, often barely perceptible except at the anterior commissure. Dorsal valve with sulcus originating at the umbo, mean width in a sample of 23 valves being 2·84 mm. (var. 0·136) at the 5 mm. growth stage ; at between 3–8 mm. (mode 6 mm.) from the umbo this flattens out and is replaced by a low, gentle fold producing a gently plicate anterior commissure. Ornamentation of costae and costellae, with freely developed secondary internal costellae on dorsal valve, 2ā arising rather late ; external 4a° and tertiaries $3a^{-1-}$, $4a^{-1-}$ moderately common. Total ribs at 3 mm. ranging from 12–22 (mode 14), and at 5 mm. 17–29 (mode 21). Concentric lamellae well developed, varying from 1 to 3, but most commonly 2, per mm. at the 5 mm. growth stage, together with finer growth lines 0·1 mm. apart.

Ventral interior with subrectangular muscle scar about one-third of valve length and about four-fifths as wide as long ; adductor scar between one-third and one-half as wide as the complete scar ; anterior margin generally convex to the front, usually indented at junctions of adductor with median lobes of diductor scars on either side ; adductor scars usually extend slightly forward of diductor scars, but many terminate slightly posterior to them.

Dorsal interior with thin blade-like brachiophores, diverging at about 90° to bound the notothyrium ; notothyrial platform thick with low median ridge extending anteriorly to divide subquadrate adductor scars, whose limits are poorly defined. Cardinal process a simple, fairly strong, ridge.

	Length	Width
Holotype. Dorsal valve (BB.30174)	8·7 mm.	c. 11 mm.
Paratypes. Dorsal valve (BB.30175)	10·4 mm.	c. 14 mm.
Ventral valve (BB.30176)	13·9 mm.	13·1 mm.
Ventral valve (BB.30177)	10·0 mm.	12·1 mm.
Damaged dorsal valve (BB.30178)	—	14·6 mm.
Ventral fragment (BB.30179)	12·7 mm.	—
Dorsal fragment (BB.30180)	—	—
Young dorsal valve (BB.30181)	c. 3·5 mm.	5·9 mm.

Discussion. In view of the common occurrence of M'Coy's species *Glyptorthis crispa* in faunal lists of the British Middle and Upper Ordovician strata, a brief review of that species seems necessary, although the forms that have been figured and described under that name are all quite distinct from the Portrane shells.

M'Coy (1846 : 29) recorded his species *Orthis crispa* as occurring rarely in the Bardahessiagh Beds, Pomeroy, of Caradocian age (Harper 1948 : 50) ; occurring commonly from Tramore, where Reed (1899 : 760) also recorded the species as being common in his stage 2 of the Tramore Limestone series, of mid-Ordovician age ; and rarely in the Tirnaskea Beds at Pomeroy, these beds being equivalent to the Drummuck in age (Fearnsides, Elles & Smith 1907 : 116).

M'Coy's diagnosis, as observed by Reed (1917 : 843) was too brief ; but it is likely that the original description and figure would be based on the commonly occurring Tramore form rather than on the rare Pomeroy shells ascribed to the species.

Accordingly it is here proposed to restrict *Glyptorthis crispa* to the form occurring in the Tramore Limestone, and forms conspecific with it. Reed (1899 : 761) mentioned the variability of the Tramore shells and suggested that more than one species may be present ; while some features of these shells show considerable variation, other characters such as the very fine ornamentation and the dorsibiconvexity seem to be constant regardless of the actual thickness or outline of the valves in the few specimens examined by the writer. For two of these ventral valves, 41 and 45 ribs were counted at the 5 mm. growth stage ; for the Portrane material 15–24 ribs were recorded for 2, 1, 2, 4, 2, 2, 2, 0, 4, 5 specimens respectively at this growth stage, the apparent bimodality of this distribution being due to a generation of costellae sometimes being inserted relatively early.

M'Coy (1852 : 216) gave a fuller description of " *Orthis crispa* ", which was based on material of Upper Bala age from the Bala district. His figured specimen (pl. 1, H, fig. 43) shows 31 ribs at the 5 mm. growth stage, apparently having an ornamentation much coarser than the Tramore shells and more like the shells from the Girvan Ashgillian Beds ascribed by Reed (1917 : 842) to *G. crispa ;* Reed's figured exterior of a dorsal valve (pl. 8, fig. 3) shows 35 ribs at the 5 mm. growth stage. The dorsal

valves of the Portrane sample show 17–29 ribs on 3, 1, 3, 3, 7, 4, 2, 3, 1, 0, 0, 1, 1 specimens respectively, higher figures than for the ventral valve, as is to be expected.

The first account of "*G. crispa*" in which the interiors are figured is that of Reed (1917, pl. 8, figs. 4–7). These Girvan shells differ from the Portrane valves in having a ventral adductor scar which is greater than half the width of the complete scar, in having a dorsi-biconvex profile, and in lacking the dorsal umbonal sulcus. They further possess a finer radial ornamentation.

Another species from the Drummuck Starfish Bed is *Glyptorthis speciosa*, only one external impression of a ventral valve being known (Reed 1944 : 215). This differs from the Portrane valves in its semicircular outline with the maximum width along the hinge-line, more ribs (27 at the 5 mm. growth stage) and a much more pronounced ventral fold.

Reed's Pomeroy species, *G. transita*, based on a solitary dorsal interior (1952: 41, pl. 1, fig. 8) is inadequately described, but apparently also has its maximum width at the hinge-line and cardinal angles of less than 90°.

The Portrane shell is much closer to *G. balclatchiensis* than to any of the above forms, there being no significant difference in the outline of the valves. Williams (1962, table 11) gives data for the dorsal valves of the Scottish shells ; for the Portrane sample the statistics are as follows : $n = 29$; $\bar{l}$ (var. l) = 6·62 (5·16) mm. ; $\bar{w}$ (var. w) = 9·11 (9·70) mm. ; r = 0·9154 ; a (var. a) = 1·371 (0·01129).

Both also possess an incipient dorsal sulcus persisting for about the same distance, but whilst 3/9 of these Scottish shells possess a sulcus which persists into the adult stage, the feature was lost in all of 35 Portrane valves and replaced by a fold in 25 of these.

At the 5 mm. growth stage 1–3 concentric lamellae per mm. were recorded on 8, 17, 4 Portrane dorsal valves respectively, which is significantly coarser at the 5% level than the 2–4 lamellae on 9, 15, 3 valves respectively recorded by Williams (1962 : 110) for the Scottish shells.

The frequencies of the more important ribs from a sample of 34 valves, including small valves and valves which were broken or too distorted for all the ribs to be identified, are listed in order of abundance as follows :—
$4a^-$ (31), $3a^-$ (30), $1a^-$ (27), $5a^-$ (21), $2a^-$ (16), $4a^\circ$ (16), $3a^-1^-$ (10), $4a^-1^-$ (10), $6a^-$ (7). Ribs occurring less than seven times (c. 20%) not included.

TABLE 2

$2a^-$) $4a^-$	0/38 (1)
$2a^-$) $3a^-$	1/42
$3a^-$) $4a^-$	6/20 (15)
$4a^\circ$) $5a^-$	4/23 (2)
$5a^\circ$) $5a^-$	1/22 (1)
$2a^-$) $3a^-1^-$	18/20 (1)

TABLE 2. Ribbing relationships expressed as frequencies of occurrence in dorsal valves of *Glyptorthis maritima* sp. nov. The figures in brackets indicate the frequency of specimens where the ribs arose too close together for the earlier one to be stated categorically.

The data on the rib patterns for the Portrane shells show several differences when compared with those given by Williams for *G. balclatchiensis*, although the two are similar in many respects. In the Portrane shells, 4a° is of moderately common occurrence, as are the tertiary ribs 3a⁻1⁻ and 4a⁻1⁻, in contrast to *G. balclatchiensis*. A comparison of the ribbing relationships shows the most striking feature of *G. maritima* to be the very late development of 2a⁻ (Table 2), and a contingency test comparing the insertion of 2a⁻ relative to 4a⁻ shows it to be significantly later in the Portrane valves than in the Girvan shells (P = ·023).

The maximum length of the ventral muscle scar relative to the valve length for 10 Portrane valves had a mean value of 33·9% (var. 16·1) ; a comparison with the 5 specimens of *G. balclatchiensis* whose mean is 40·2% (var. 10·25) (Williams 1962: 111) reveals a significant difference (·01 > P > ·001). Due to the large flanking diductors in the older valves, Williams used the length of the scar along the median line instead of the maximum length as used here ; as it is shown that the maximum length of the Portrane scars is significantly shorter than the median length of the Scottish shells, the difference would be even greater if comparison could have been made with the maximum length in the Scottish shells.

Summarising, significant differences are to be found between *G. maritima* and *G. balclatchiensis* in the impersistence of the dorsal sulcus, the coarser imbricate ornamentation, the greater development of ribs 4a°, 3a⁻1⁻, 4a⁻1⁻ and the late development of 2a⁻, and in the shorter ventral muscle scar of the former.

American shells of similar age may be dismissed fairly quickly as having no very close affinities to the Portrane valves ; *G. pulchra* from the Maquoketa shale has a longer ventral muscle field, finer ornamentation and very pronounced and persistent dorsal sulcus (Wang 1949 : 4). The type species, *G. insculpta*, also occurring in the Richmondian, again has a much finer ornamentation and a persistent dorsal sulcus (Hall 1847 : 125 ; Foerste 1924 : 110 ; Schuchert & Cooper 1932, pl. 6). *G. crispata* from the late Edenian–early Maysvillian Lorraine formation of New York differs in the very much shallower ventral valve and the larger number of ribs developed (Foerste 1914 : 258) ; *G. bellarugosa*, whose type specimens come from the Trenton Decorah formation (Cooper 1956 : 363), was recorded by Roy (1941 : 88) from the Richmond at Silliman's Fossil Mount. Roy's solitary specimen was retained in that species by Cloud (Miller *et al* 1954 : 13) ; the age of this fauna is however very much in dispute as the brachiopods, trilobites and ostracods generally indicate a Middle Ordovician age, whilst the cephalopods are of dominantly Upper Ordovician affinities (Miller 1954 : 43). The type specimens of *G. bellarugosa* differ from the Portrane valves most obviously in the long ventral muscle scar, persistent dorsal sulcus and finer ornamentation. No species of the genus are yet known from the Upper Ordovician of Percé or of Anticosti Island.

The following statistical data were obtained for the Portrane species.

1. *Ventral Exterior.*

(a) *Outline—length (l): width (w) of valve:* n=14; $\bar{l}$ (var. l)=7·98 (11.264) mm.; $\bar{w}$ (var. w)=9·49 (9·172) mm.; r=0·9026 ; $\overline{\log_e l}$ (var. $\log_e$ l)=1·9954

(0·1630) ; $\overline{\log_e w}$ (var. $\log_e$ w)=2·2018 (0·0969) ; r_e=0·9095 ; α (var. α)= 0·7709 (0·009179).

(b) *Profile—length* (*l*) *: thickness* (*t*) *of valves :* n=12 ; $\bar{l}$ (var. l)=8·44 (9·412) mm.; $\bar{t}$ (var. t)=2·91 (1·066) mm.; r=0·8156 ; a (var. a)=0·3365 (0·003791).

(c) *Length of interarea* (*x*) *to valve length* (*y*). n=13 ; $\bar{x}$ (var. x)=1·79 (0·2108) mm.; $\bar{y}$ (var. y)=8·93 (6·211) mm.; r=0·8674 ; a (var. a)=5·429 (0·6634).

(d) *Length* (*l*) *: width* (*w*) *of interarea.* n=13 ; $\bar{l}$ (var. l)=1·73 (0·180) mm.; $\bar{w}$ (var. w)=8·20 (3·301) mm.; r=0·6498 ; a (var. a)=4·282 (0·9629).

2. *Ventral muscle scar.*

(a) *Length* (*l*) *: width of muscle scar* (*w*). n=20 ; $\bar{l}$ (var. l)=3·15 (1·140) mm.; $\bar{w}$ (var. w)=2·61 (0·3694) mm.; r=0·8549 ; a (var. a)=0·5693 (0·004846).

(b) *Length of muscle scar* (*ms*) *: valve length* (*vl*). n=10 ; $\overline{ms}$ (var. ms)=2·84 (1·170) mm.; $\overline{vl}$ (var. vl)=8·13 (6·836) mm.; r=0·9740 ; a (var. a)=2·417 (0·03744).

(c) *Ratio of width of adductor scar : width of complete scar.* Five valves show a mean of 39·4% (var. 52·25) for this statistic.

3. The dorsal ornamentation shows a density of 2–5 ribs per 2 mm. medianly at the 5 mm. growth stage on 6, 19, 7, 4 valves respectively. The number of ribs present in the sulcus are 2, 3 for 32, 7 valves at the 3 mm. growth stage, and 2–6 on 5, 12, 10, 5, 2 valves at the 5 mm. growth stage, respectively.

Glyptorthis maritima magna subsp. nov.

(Pl. 3, figs. 1–6, 18)

Diagnosis. Large *Glyptorthis* of subelliptical outline ; ventri-biconvex, becoming dorsi-biconvex with increased size. Ventral valve with gently rounded sulcus developing at about the 1 cm. growth stage by the depression of an initial strong median costa at the umbo. Dorsal valve evenly convex, strongly so in larger valves with the narrow umbonal sulcus replaced by a rounded fold developing near the 1 cm. growth stage and becoming pronounced anteriorly. Concentric ornamentation of growth lamellae, 2 and 3 per mm. being recorded for two valves at the 5 mm. growth stage. Radial ornamentation of angular costae and costellae ; total ribs on ventral valves at 3 mm. growth stage varying from 12–15 and at 5 mm. growth stage 12–16 with the mode at 14 in each case.

Ventral interior with strong teeth and muscle scar similar to *G. maritima* s.s. but often showing considerable thickening marginally, especially at the front ; a pair of well defined sub-parallel *vascula media* pass anteriorly from the outer sides of adductor scar.

Dorsal interior with stout blade-like brachiophores, thick notothyrial platform with high ridge-like cardinal process. Muscle scar subquadrate, over half valve length, unequally divided into small arcuate posterior scar which bounds the curved, posterolateral part of large quadrant-shaped anterior scar. Muscle field divided longitudinally by sharp narrow ridge extending forward from notothyrial platform ;

anterior scars also divided longitudinally by low ridge which reaches a pronounced crest along anterior margin of scar. Pallial markings often well preserved.

		Length	Width
Holotype.	Dorsal valve (BB.30182) .	. 20·9 mm.	24·0 mm.
Paratypes.	Incomplete ventral valve (BB.30183)	c. 19 mm.	c. 22 mm.
	Incomplete ventral valve (BB.30184)	11·6 mm.	c. 16 mm.
	Incomplete dorsal valve (BB.30185)	—	—
	Incomplete dorsal valve (BB.30186)	12·2 mm.	—

Discussion. This subspecies differs from *G. maritima* s.s. in several features ; it attains a much greater size, develops a pronounced dorsal fold and ventral sulcus, has much more pronounced internal structures, and possesses a coarse radial ornamentation.

A consideration of this ornamentation is most important. One, two ribs per 2 mm. at the 5 mm. growth stage were recorded for 1, 6 dorsal valves of the larger species, compared with 2–5 ribs on 6, 19, 7, 4 valves of the smaller species in the same position. A contingency test shows the ribbing to be significantly coarser in the larger sub-species ($P < \cdot 001$).

The total numbers of ribs on the ventral valve at the 3 mm. growth stage for the large subspecies were 12–15 on 1, 2, 2, 1, specimens compared with 11–21 on 1, 0, 10, 6, 8, 2, 0, 1, 0, 0, 2 valves respectively for *G. maritima* s.s.; the two forms cannot be separated on this character. At the 5 mm. growth stage 12–16 ribs occur on 1, 1, 3, 1, 2 specimens of *G. maritima magna*, compared with 15–24 ribs on 2, 1, 2, 4, 2, 2, 2, 0, 4, 5 specimens of *G. maritima* s.s.; this does indicate that significantly fewer ribs are present on *G. maritima magna* ($P < \cdot 001$).

Thus in *G. maritima magna* the rib pattern of early stages persists until between about 7–10 mm. before branching occurs, the ribs being consequently coarser ; so that although the ribbing of the two subspecies is comparable at the 3 mm. growth stage, the delayed branching of *G. maritima magna* produces an ornamentation of much coarser aspect.

Whilst many of the shells with the coarser ornamentation attain a length of 20 mm. or more, others are of sizes comparable to the specimens of *G. maritima* s.s. The development of a pronounced dorsal fold is a natural continuation of the trend seen in *G. maritima* s.s., but as the presence of the coarse ornamentation on smaller shells shows, these valves are not simply large specimens of *G. maritima* s.s.

The evidence would indicate that these shells probably lived in a more favourable ecological niche than those of *G. maritima* s.s., so that they grew to a larger size and at a more rapid rate, the appearance of additional costellae being dependent on a definite stage of development rather than the attainment of a particular size of the shell. Hence where a more favourable environment encouraged more rapid growth

this stage occurred after a larger quantity of shell substance had been secreted, and was thus recorded in a more anterior position on the shell surface. Accordingly these valves are designated as a separate subspecies of *Glyptorthis maritima*.

The delay in the insertion of additional costellae which produces this coarse ornamentation in the first centimetre or so of shell growth, gives the shells an aspect reminiscent of *Glyptorthis morkokiana* described from the Ashgillian beds of the Siberian Platform by Nikiforova (1961 : 93, pl. 8, figs. 1–5). This species differs from the Portrane valves particularly in having a persistent dorsal sulcus, which shows no tendency to revert into a fold.

Foerste (1924 : 110) commented on a similar retardation of insertion of some of the ribs in specimens of *G. insculpta*, which also causes some specimens to appear more coarsely ribbed than others. He regards these merely as more robust individuals : no other comparisons are made between these forms and the finer ribbed shells, but it seems probable that present day palaeontological practice may show that more than one morphological species is present in that material.

Genus ***PTYCHOPLEURELLA*** Schuchert & Cooper 1931

Ptychopleurella twenhofeli nom. nov.

(Pl. 3, figs. 7, 8, 10–12, 19, 20, 22, 24, 28)

1914 *Orthis? lamellosa* Twenhofel : 24, pl. 1, figs. 1–3.
1928 *Orthis? lamellosa* Twenhofel ; Twenhofel : 175, pl. 15, figs. 6, 8, 9 (non fig. 7).

Description. Small subquadrate to subrectangular biconvex shells, thickness about three-quarters of ventral length. Ventral valve about four-fifths as long as wide, strongly pyramidal, slightly arched medianly in anterior profile, sometimes resulting in a low fold ; interarea flat, catacline, or very slightly curved apsacline, about two-fifths as long as wide, with slit-like delthyrium due to restriction by lateral plates. Dorsal valve longer than ventral in commissural length (see Text-fig. 1) with pronounced median sulcus ; interarea short, anacline, almost one-sixth as long as wide. Ornamentation of pronounced concentric lamellae, lying close to shell with density ranging from 3 to 5 per mm., most commonly 3 or 4 at the 3 mm. growth stage ; and of simple costae, typically 13 (range 11–16) on ventral valves which have a median costa with six costae on either flank ; and 12 to 14 on dorsal valves, which have a basic pattern of two costae in the sulcus and five on each flank, with the possibility of an extra rib arising on both or either flanks

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Fig. 1. Diagrammatic lateral views of the ventral valves of some genera which show different values for valve length according to the direction in which the valve is measured. C = commissural length, defined as the length of the valve measured in the plane of commissure ; S = surface length, the maximum length from the umbo to the most anterior part of the valve. This latter is *usually* the maximum valve length. 1. *Schizophorella*, in which the sulcus forms a pronounced tongue ; 2. *Ptychopleurella*, with a high catacline interarea ; 3. *Vellamo*, in which the procline interarea makes C the maximum valve length ; 4. *Kullervo*, again with a high interarea producing different lengths for C and S.

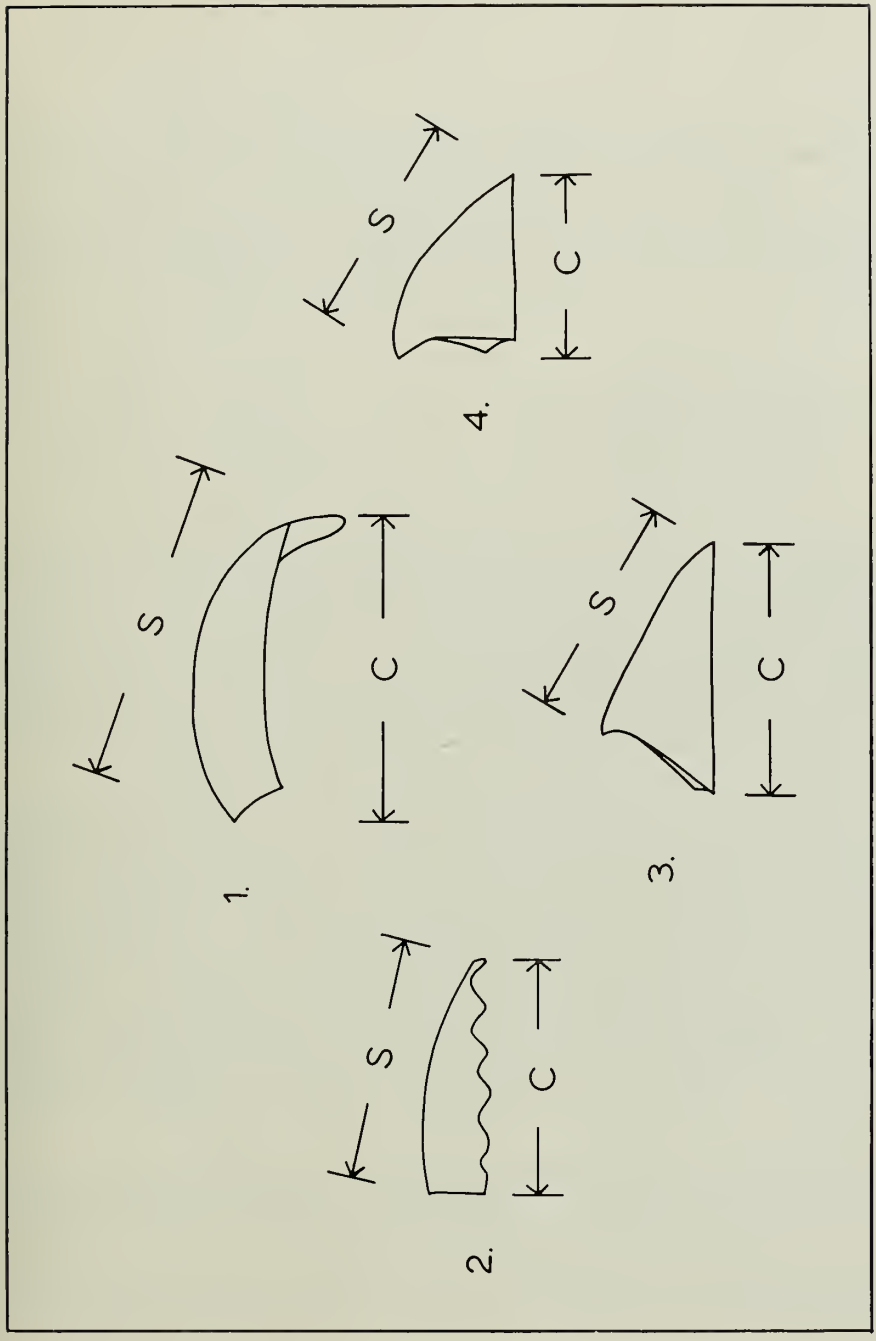

FIG. 1

between the outermost rib and the hinge-line. Extra ribs over the mode of 13 in the ventral valve developed in corresponding positions ; only one valve shows a bifurcating rib.

Ventral interior with teeth lacking support or with extremely short receding dental plates ; muscle field very small, restricted to umbonal region and of cordate to sub-triangular outline ; delicate concave apical plate present on some of the better preserved specimens. Dorsal cardinalia composed of low simple cardinal process situated on thick notothyrial platform, from which a ridge extends anteriorly corresponding in position to the external sulcus. Brachiophores short, stout, narrowly divergent ; muscle field characteristically quadripartite, but seldom preserved.

Figured Specimens	Length	Width
Complete shell (BB.30187) . . .	5·1 mm.	4·8 mm.
Ventral valve (BB.30188) . . .	4·5 mm.	5·1 mm.
Dorsal valve (BB.30189)	4·6 mm.	5·2 mm.

Discussion. As the nature of the ornamentation of these small shells is of considerable importance in specific identification, the detailed data on the variation found in the Portrane sample are here included as follows. In the best preserved ventral valves 11 to 16 costae were recorded on 1, 0, 73, 5, 1, 1 specimens. In deformed, partially obliterated and broken valves, 13, 14 and 15 ribs were recorded for 295, 5 and 1 valves, again stressing the mode of 13 ribs. The best dorsal valves show 12, 13 and 14 ribs on 35, 20 and 30 valves ; the remaining 346 of the sample also possess the same basic pattern as stated in the description above.

Twenhofel's species *Orthis? lamellosa* is a member of the genus *Ptychopleurella* as defined by Schuchert & Cooper. Unfortunately, *Orthidium lamellosum* Raymond also belongs to the same genus, and has priority over Twenhofel's species which is accordingly here given a new name, *Ptychopleurella twenhofeli*. The holotype comes from the Ellis Bay Formation of Anticosti Island and is of Gamachian age (uppermost Ordovician). The following species are considered to be closest to the Portrane and Anticosti forms : *P. keisleyensis* (Reed 1897) from the Ashgillian limestone at Keisley ; *P. sublamellosa* (Cooper 1930) from the Whitehead Formation of Percé, Quebec ; *P. lapworthi* (Davidson 1883, *pars.*) from the Whitehouse Group, Girvan, and from older rocks ; and *P. uniplicata* Cooper 1956 (Benbolt Formation, Virginia).

P. rectangulata lacinata Williams from the Stinchar Limestone at Girvan also resembles the Portrane form, but may be distinguished by the significantly larger number of ribs on the Girvan shells. For the dorsal valve Williams (1962 : 112) records 11 to 18 costae inclusive as being displayed by 1, 1, 5, 16, 12, 4, 2, 2 individuals respectively. A χ^2 test shows that the number on the Portrane shells is significantly smaller ($P < \cdot 001$).

TABLE 3

	11–13 costae	14–18 costae
Stinchar frequency	7	36
Portrane frequency	55	30

TABLE 3. Table for χ^2 test comparing the ribbing densities of *P. rectangulata lacinata* from the Stinchar with *P. twenhofeli* from Portrane.

P. uniplicata Cooper possesses the number of ribs typical of the Portrane form, but has the ventral median costa raised to form a low fold. This feature does occur in the Portrane form, but here the fold is extremely variable with 1, 3 or 5 ribs raised to form a low fold, or else showing no development of a fold whatever. The outline of the ventral valve figured by Cooper (1956, pl. 49, H, figs. 43, 44) is quite different from the Portrane species in having a hinge width : valve width ratio of only 73% and cardinal angles which are very much more obtuse than those of *P. twenhofeli*, those of the latter being barely greater than a right angle.

A certain amount of confusion exists over Davidson's species *Orthis lapworthi*, which was placed in the genus *Ptychopleurella* by Schuchert & Cooper (1932 : 92). According to Reed (1917 : 843) the material figured by Davidson, and thus the type material, came from the Balclatchie Conglomerate only, and not from Shalloch Mill. Reed added that Davidson's figures and descriptions were unsatisfactory, and questioned the specific separation of *O. lapworthi* from *O. balclatchiensis* Davidson (*Glyptorthis*), the young forms of the latter being indistinguishable from *O. lapworthi*.

This last opinion was followed by Williams (1962 : 109), who included the specimens figured by Reed from the Balclatchie Conglomerate (except pl. 8, fig. 12) with the species *Glyptorthis balclatchiensis*.

The Portrane *Glyptorthis*, like the Girvan form, shows a costate condition in the umbonal region similar to that of *Ptychopleurella* ; in spite of this, and the similar development of a sulcus in the early stages, other features generally enable the two genera to be clearly separated. *Ptychopleurella* differs from young specimens of the Portrane *Glyptorthis* in showing a flat catacline or slightly curved apsacline ventral interarea whose length : width ratio is significantly larger ; and in the development of a slit-like delthyrium, resulting from its restriction by lateral plates.

Whether or not the Balclatchie specimens of *O. lapworthi* are the young of *Glyptorthis balclatchiensis*, they differ from the Portrane *Ptychopleurella* in having more costellae (ranging from 14 to 20 on the ? ventral valves—Williams 1962 : 110) although the outline and profile of the two are very similar. The shells from Shalloch Mill (Reed : pl. 8, figs. 15–17) show 12 ribs on one dorsal valve, a typical pattern for the Portrane shells, but differ in having rounded and strongly obtuse cardinal angles. The ventral valve (fig. 15) shows 14 ribs, and has no median rib judging from Reed's reconstruction of the outline. It appears more likely, however, that the specimen is deformed with the stronger median rib twisted to the left anteriorly.

The solitary ventral valve of *P. keisleyensis* possesses 16 ribs (Reed 1897*a*, pl. 6, fig. 1). Of the better ventral valves from Portrane, only 1 out of 81 specimens

showed as many ribs, with none amongst 301 less well preserved shells. The Keisley specimen otherwise is close to *P. twenhofeli*, although the median rib appears to be lacking, and Reed also states that there is a faint indication of a median sulcus present.

According to Cooper (1930), *P. sublamellosa* differs from the Anticosti specimens of *P. twenhofeli* in its smaller size, and in having a conspicuously larger median rib in the ventral valve. The smaller size is a questionable specific character ; and the length : width ratio for the specimens whose measurements are given by Cooper (1930 : 267), i.e.

	Length	Width
Ventral valve	2 mm.	3 mm.
Ventral valve	2·5 mm.	3 mm.
Dorsal valve	3·3 mm.	3·5 mm.

clearly falls within the range of variation of that of *P. twenhofeli*, and within the actual size range of the Portrane shells. The specimen figured by Twenhofel (1928, pl. 15, fig. 9) has a width of 7 mm., whilst the widest of the Portrane specimens is 6·5 mm. Thus the Portrane shells appear almost to bridge the gap, in size at least, between the Anticosti and Percé shells. It seems doubtful whether the specimen from Battery Point (in the older Vauréal Formation) mentioned by Twenhofel (1928 : 175), which is 13 mm. wide and has 18 " small plications ", does belong to the same species ; unfortunately this is not figured. The conspicuously larger median rib on *P. sublamellosa* may be accounted for by the fact that in young shells, the slightly later appearance of its two bounding costae relative to the median costa and the other costae gives this appearance, the difference becoming less noticeable with increased growth of the valves. This situation is in fact to be observed in *P. twenhofeli* (Twenhofel 1928, pl. 15, fig. 8). *P. sublamellosa* shows a convex anterior margin in contrast to the straight or very gently convex margin in typical *P. twenhofeli* ; but the growth lines of the latter show that in young stages it too had a convex margin, the straightening being a reflection of the development of fold and sulcus.

There seems no doubt that the Portrane shells are conspecific with the Ellis Bay shells ; and on the available evidence (and in the absence of a good sample) it appears that *P. sublamellosa* is also conspecific with *P. twenhofeli*. Closely related to *P. twenhofeli* are the two British species *P. keisleyensis* and the Whitehouse specimens of " *P. lapworthi* ".

The following statistical data were obtained for the various attributes of shell shape.

(a) *Length (l) : width (w) of ventral valve.* n=76; $\bar{l}$ (var. l)=3·67 (0·705) mm.; $\overline{\log_e l}$ (var. $\log_e$ l)=1·275 (0·0507) ; $\bar{w}$ (var. w)=4·57 (0·66) mm. ; $\overline{\log_e w}$ (var. $\log_e$ w)=1·504 (0·0315) ; r=0·8539; r_e=0·8609; α (var. α)=0·788 (0·00217).

(b) *Length (l) : width (w) of dorsal valve.* n=64 ; $\bar{l}$ (var. l)=3·75 (0·731) mm. ; $\overline{\log_e l}$ (var. $\log_e$ l)=1·296 (0·0507) ; $\bar{w}$ (var. w)=4·49 (0·642) mm. ; $\overline{\log_e w}$ (var. $\log_e$ w)=1·476 (0·0315) ; r=0·7868 ; r_e=0·8154 ; α (var. α)=0·788 (0·00336).

(c) *Ventral length (l) : shell thickness (t).* n=20 ; $\bar{l}$ (var. l)=3·22 (0·596) mm. ; $\overline{\log_e l}$ (var. $\log_e$ l)=1·1412 (0·0564) ; $\bar{t}$ (var. t)=2·39 (0·352) mm. ; $\overline{\log_e t}$ (var. $\log_e$ t)=0·0841 (0·0602) ; r=0·9108 ; r_e=0·9200 ; a (var. a)=0·77 (0·0056).

(d) *Width of hinge-line (hl) ; valve width (vw).* (ventral and dorsal valves) n=73 ; $\overline{hl}$ (var. hl)=3·8 (0·43) mm. ; $\overline{vw}$ (var. vw)=4·53 (0·67) mm. ; r=0·8706 ; a (var. a)=1·24 (0·00524).

(e) *Length (l) : width (w) of ventral interarea.* n=44 ; $\bar{l}$ (var. l)=1·67 (0·141) mm. ; $\overline{\log_e l}$ (var. $\log_e$ l)=0·488 (0·050) ; $\bar{w}$ (var. w)=4·14 (0·443) mm. ; $\overline{\log_e w}$ (var. $\log_e$ w)=1·408 (0·0255) ; r=0·693 ; r_e=0·662 ; α (var. α)=0·715 (0·00685).

(f) *Length (l) : width (w) of dorsal interarea.* n=30 ; $\bar{l}$ (var. l)=0·52 (0·009) mm. ; $\bar{w}$ (var. w)=3·49 (0·329) mm. ; r=0·414 ; a (var. a)=6·047 (1·081).

" T " tests indicate allometric effects in (a), (b) and (e). The log values are also included for (c), for although a test for allometry proved negative, this may be due to the small size of the sample.

Ptychopleurella separata sp. nov.

(Pl. 3, figs. 9, 13–16)

Diagnosis. *Ptychopleurella* of subrectangular to subquadrate outline, with slightly convex anterior margin ; profile ventri-biconvex. Ventral valve pyramidal, about two-fifths as deep as long, with flat, procline or slightly apsacline interarea almost a third as long as wide, its width being just less than the maximum valve width. Delthyrium restricted to narrow slit by lateral plates. Ornamentation costellate ; on ventral valve five strong costae arise at the umbo ; another arising later between hinge-line and outermost costa. Median costa branching late (after 1 mm. in 9 out of 11 shells) to produce a costella on either side ; rib 2 branches to produce an external costella (2a°), two of the valves also showing a 3a°. Corresponding costellae on dorsal exterior are internal. Six ventral valves show 9, 10, 11 ribs on 2, 2, and 2 respectively. Density of concentric lamellae 3–5 per mm. on 2, 5, 2 valves. Typical small umbonal ventral muscle field seen in one valve only, with diductors extending slightly beyond but not enclosing adductor scars.

		Length	Width
Holotype.	Ventral valve (BB.30190) . .	4·8 mm.	6·9 mm.
Paratype.	Dorsal valve (BB.30191) . .	4·3 mm.	6·5 mm.

Discussion. Some dozen or so specimens of *Ptychopleurella* are separated from the associated *P. twenhofeli*, being quite distinct from that form in having a costellate ribbing pattern, and at the same time having fewer ribs developed.

The outline of the ventral valve shows considerable variation from subrectangular to subquadrate. In a small sample of 6 valves for which data was obtained, the mean length : width percentage was 75·6% (var. 117·5). In contrast, the variance of the interarea was extremely small ; for the sample of five ventral valves, the mean length : width percentage of the interarea was 29·6% (var. 3·3), and its width relative to the maximum valve width was 96% (var. 1·0).

The style of ornamentation seen in *P. separata* is uncommon in the genus, the majority of species having a costate radial ornamentation, except for the two ribs in the dorsal sulcus and those flanking the median rib in the ventral valve, which do tend to develop later than the rest. The only described species whose ornamentation resembles that of *P. separata* are the much younger *P. matapedia* Schuchert & Cooper and *P. bouchardi* Davidson. The former differs from *P. separata* in having both internal and external costellae developed on costae 2 and 3 of the ventral valve ; from the latter the Portrane form differs in many features, particularly in lacking the curved, more strongly apsacline ventral interarea ; in having a restricted slit-like delthyrium ; and in lacking the embayed anterior margin.

Genus ***SPINORTHIS*** nov.

Diagnosis. Semi-circular to subquadrate ventri-biconvex shells ; lateral profile of ventral valve markedly convex umbonally, flattening, then developing a strong, dorsally directed geniculation. Dorsal valve gently convex, with a reflection corresponding to the geniculation of ventral valve producing a marginal concavity. Dorsal valve with median sulcus, ventral valve with less prominent fold. Ornamentation of costae and costellae, together with extravagantly developed concentric lamellae directed outwards from shell surface to produce hollow spines where radial and concentric ornaments cross. Ventral interarea apsacline, but usually procline umbonally where accordingly develops a convex surface ; delthyrium broad, open, with beak often excavated. Dorsal interarea very short, notothyrium open.

Ventral interior with moderately developed teeth supported by long dental plates, which continue anteriorly as ridges to bound the obcordate muscle field. Median adductor scar narrow, separating the longer median lobes of diductor scars. Lateral diductor lobes and adjustor scars situated on inner surface of dental lamellae. A pair of closely opposed *vascula media* extend anteriorly from median diductor lobes.

Dorsal interior with a pair of weakly developed brachiophores diverging at over 90°. Sockets shallow ; cardinal process a simple ridge situated on a variably developed notothyrial platform which extends anteriorly as a ridge to divide the quadripartite adductor field longitudinally.

Discussion. The imbricate external surface, the ventral muscle field, and the general appearance of the dorsal cardinalia, all indicate that the affinities of this genus lie with the Glyptorthinae. It is, however, quite distinct from any of the previously described genera of this subfamily in the extreme development of the concentric lamellae, which become directed almost perpendicularly to the shell surface to form hollow spines along the line of the ribs. A second major character of the genus is the development of a geniculation in the ventral valve, making it very deep, and a corresponding deflection in the dorsal valve. This produces an external appearance similar to a productid brachiopod, as is also seen in the Productorthinae. Other resemblances to that subfamily are found in the weak development of the brachiophores, which are indeed little more than socket ridges ; and in the extremely short interarea of the dorsal valve. These features are considered to be produced as corollaries in the development of a productoid habit in this extreme form of glyptorthinid, rather than to indicate any very close relationship with the *Nicolella-Productorthis* line, for apart from the very definite glyptorthinid characters given above, *Spinorthis* lacks the chilidial plates of the Productorthinae and unlike that subfamily possesses a well developed ventral interarea.

Type species. *Spinorthis geniculata* sp. nov.

Spinorthis geniculata gen. et sp. nov.

(Pl. 5, figs. 1–8, 10–12)

Diagnosis. Subquadrate ventri-biconvex *Spinorthis* with ventral valve three-quarters as long as wide and almost half as deep as long, and pronounced geniculation developed at about 6 mm. from umbo. Slight median fold developed posterior to geniculation, corresponding to shallow but well-marked sulcus on dorsal valve, whose initial gently convex surface becomes reflected dorsally at a position corresponding to that of geniculation of ventral valve. Ventral interarea almost one-fifth as long as valve, overall attitude apsacline, but procline umbonally due to anterior twisting of umbo to produce a convex surface ; delthyrium broad, open, with umbo excavated by the pedicle ; dorsal interarea extremely short.

Radial ornamentation of sharply crested costae and costellae, with dominantly dichotomous branching on ventral valve and intercalation on the dorsal ; radial ornamentation of strong concentric frills situated at about every mm., with finer growth lines (about one per 0·1 mm.) occasionally seen. Stout hollow spines occur where radial and concentric ornamentations cross.

Ventral muscle field obcordate, about two-fifths as long as valve ; median adductor scar narrow, less than one-quarter of the width of that of the combined adductor and median diductor lobe scars, this latter width being about two-thirds of the length of the complete scar. Adductor scar about three-quarters of the length of diductor scars. Cardinalia composed of simple cardinal process situated on variably developed notothyrial platform ; brachiophores weak, diverging at a mean angle of 100° (var. 119°) in a sample of 9 specimens.

		Maximum Length	Width
Holotype.	Ventral valve (BB.30192) .	. 10·6 mm.	11·9 mm.
Paratypes.	Dorsal valve (BB.30193) .	. 9·8 mm.	c. 16 mm.
	Dorsal valve (BB.30194) .	. 9·9 mm.	11·6 mm.
	Ventral valve (BB.30195) .	. 9·9 mm.	12·2 mm.
	Broken ventral valve (BB.30196) . . .	—	—
	Broken dorsal valve (BB.30197) . . .	—	—
	Dorsal fragment (BB.30198)	. —	—

Discussion. The sudden increase in convexity of the ventral valve in later growth stages suggests allometric growth, a feature which is confirmed statistically (data given below). This type of development affects the valve outline (the shells losing their rather transverse appearance with increased growth) as well as the convexity, the strong convexity of the umbonal stages usually flattening before the development of the geniculation, which occurs at a mean distance of 6·35 mm. (var. 0·49) from the umbo in a sample of 16 ventral valves. Two deformed valves, which are not included in these figures, show a rather later geniculation (7·9, 8·5 mm.). The corresponding deflection of the dorsal shell occurs at a mean distance of 7·15 mm. (var. 0·56) in a sample of 10 valves.

The dorsal sulcus is shallow, gently curved, and bound by a strong costa on either side, with a mean width of 1·5 mm. (var. 0·0525) at 3 mm. from the umbo in a sample of 21 valves. Within the sulcus a late costa arises medianly usually between 2 to 3 mm. from the umbo ; 0–4 ribs are developed in the sulcus of 11, 5, 0, 0, 0 valves at 2 mm.; 0, 18, 2, 0, 0 valves by 3 mm.; and 0, 2, 2, 2, 1 valves at 5 mm., respectively, the additional ribs being costellae.

The basic ribbing pattern of the dorsal valves is of three strong costae on either flank, with weaker costae sometimes developed outside these ; costellae also develop, sometimes by splitting, but normally by intercalation. The total numbers of ribs (including those in the sulcus) recorded at various growth stages are as follows :— At 2 mm., 5–8 ribs occur on 1, 7, 4, 2, specimens ; at 3 mm., 7–11 ribs occur on 4, 2, 3, 2, 5 specimens respectively ; whilst at 5 mm. counts of 11, 12, 13, 15, 15 were taken on 5 valves. The mean wave-length of the ribs taken at a distance of 3 mm. from the umbo for a sample of 15 dorsal valves is 0·71 mm. (var. 0·03). On the geniculate part of the ventral valve the ribs are less prominent and much wider spaced, whilst some ribs are barely perceptible or missing completely from the valve surface after the geniculation.

For the concentric ornamentation, 2, 3 and 4 lamellae are present over the 2 to 4 mm. distance anterior to the ventral umbo on 5, 3 and 1 specimens respectively.

Whilst the dorsal interarea is so small as to be barely visible in many specimens, the ventral interarea has a mean length : width % of 20·5 (var. 60·8) in 7 shells, its mean length being 18·6% (var. 8·3) of that of the valve length for 5 specimens.

In carrying out a statistical assessment of the muscle scars, the measurement of the width of the scar was taken across the adductor and the median diductor lobes

on either side. The lateral diductor lobes are situated on the inner surfaces of the dental plates. Accordingly, they are in a plane of anything up to 90° to that of the median lobes, and because of this variability have been excluded from the statistical data. Seven valves show a mean width : length % for the muscle scar as thus restricted of 65·4% (var. 110·5), the mean length of the scar to the valve length being 39·8% (var. 19·8) in 6 valves. Four valves show the diductors to extend in front of the adductors by 12, 26, 30, 34% of the diductor length, whilst the width of the adductors : width of the muscle scar is 22, 22 and 26% in three valves.

Statistical data for the valve shape is as follows:—

(1) *Length (l) : width (w) of the ventral valve:*—n=18 ; $\bar{l}$ (var. l)=6·52 mm. (11·12) ; $\bar{w}$ (var. w)=8·87 mm. (11·66) ; r=0·862 ; $\overline{\log_e l}$ (var. $\log_e$ l)=1·7588 (0·2323) ; $\overline{\log_e w}$ (var. $\log_e$ w)=2·1137 (0·1381) ; r_e=0·875 ; α (var. α)=0·7709 (0·009545).

(2) *Length (l) : thickness (t) of the ventral valve:*—n=10 ; $\bar{l}$ (var. l)=9·53 mm. (2·59) ; $\bar{t}$ (var. t)=4·29 mm. (1·40) ; r=0·7805 ; $\overline{\log_e l}$ (var. $\log_e$ l)=2·2405 (0·0279) ; $\overline{\log_e t}$ (var. $\log_e$ t)=1·4196 (0·0734) ; r_e=0·789 ; α (var. α)=1·622 (0·07216).

(3) *Length (l) : width (w) of dorsal valve:*—n=10 ; $\bar{l}$ (var. l)=6·73 mm. (6·99) ; $\bar{w}$ (var. w)=8·57 mm. (14·26) ; r=0·8414 ; a (var. a)=1·429 (0·07446).

Family **DINORTHIDAE** Schuchert & Cooper 1931

Genus ***PLAESIOMYS*** Hall & Clarke 1892

Plaesiomys porcata (M'Coy)

(Pl. 4, figs. 1–12)

1846 *Orthis porcata* M'Coy : 32, pl. 3, fig. 14.
1853 *Orthis porcata* M'Coy ; Medlicott : 268.
1861 *Orthis porcata* M'Coy ; Baily : 11 (*pars*).
?1870 *Orthis porcata* M'Coy ; Davidson, pl. 31, fig. 13.
1880 *Orthis porcata* M'Coy ; Baily : 81 (*pars*).
1895 *Orthis porcata* M'Coy ; Sollas : 102.

Description. Dorsi-biconvex to convexo-concave shells of transversely elliptical outline ; ventral valves about three-quarters as long as wide and one-quarter as deep as long, maximum thickness at or close to the umbo. Cardinal angles obtuse, with the hinge-line width about four-fifths of the maximum valve width. Interarea about one-fifth as long as wide, and about one-fifth as long as the valve, flat or gently curved (especially near the beak) ; attitude varying from apsacline to catacline and procline. Delthyrium normally open ; one specimen however shows what may be a concave pedicle collar at the apex. Lateral profile variable, depending on the attitude of the interarea ; where this is apsacline, the deepest part of the valve is just anterior to the umbo, after which the valve flattens ; in procline valves the beak is usually (although not invariably) the deepest part, anterior to

which the valve is flat or slightly concave. Transverse profile low, conical. Shallow sulcus developed in the young adult stages, flat or smoothly curved producing a gently plicate anterior commissure.

Dorsal valve evenly convex in both profiles, the convexity increasing relatively with age ; thickness : length ratios ranging from one-sixth to almost one-half in a large shell (35 mm. long) ; interarea less than one-tenth of the valve length, curved, orthocline to slightly apsacline. Ornamentation of rounded to sub-angular ribs with costellae developing from about 19 primary costae, the total number of ribs having a mode of 28 (range 20–35) at the 5 mm. ventral growth stage, and a mode of about 40 (range 36–48) at the 10 mm. growth stage ; shells of this latter size usually have a maximum of three ribs per sector, whilst those attaining 20 mm. may have 5 or 6 in some sectors due to the development of additional costellae at about this size.

Ventral interior with teeth supported by strong receding dental plates whose anterior continuation forms the margin to a sub-triangular to subpentagonal muscle field, extending for about one-third of the valve length and much thickened by secondary shell substance. Pedicle callist well defined ; adductor scars small, elongatedly oval, subcentral, almost enclosed by the triangular median diductor lobes ; lateral lobes usually well-developed, with adjustor scars on the inner surface of the dental plates. Ridges of the arcuate *vascula media* arise from the antero-lateral extremities of the muscle field and branch across the valve floor.

Dorsal interior with cardinalia consisting of simple brachiophores extending anteriorly for about one-sixth of the valve length, the tops diverging at about 90° (7 specimens have a mean of 89°, variance 84·3) and are supported by shell substance only, to form the inner boundary of the sockets ; the brachiophore may have a smooth or grooved inner surface, sometimes with a ventrally directed hook at its distal end. Notothyrial platform shallow, with a high cardinal process, grooved posteriorly on its antero-ventral surface where the shaft passes into a large myophore. The platform extends anteriorly as a low ridge to divide the adductor field, whose length and width are about equal, with the subtriangular anterior scars smaller than the sub-oval posterior pair. *Vascula media* and *myaria* occasionally well defined.

Figured Specimens	Length	Width
Ventral valve (BB.30199) . . .	24·1 mm.	35·7 mm.
Damaged ventral valve (BB.30200) . .	—	—
Damaged dorsal valve (BB.30201) .	35·4 mm.	c. 40 mm.

Also four ventral fragments (BB.30202–05) and four dorsal fragments (BB.30206–09).

Discussion. One of the most important characters of the genus, and indeed of the family Dinorthidae, is that of the ventral muscle field. In this species a sample of 13 valves show a mean length : width ratio for the muscle scars of 107% (var. 500·6), the high variance indicating large differences in the overall outline of the scars. The muscle field shows a well-developed pedicle callist umbonally, antero-median to which is a groove which broadens into an elongatedly oval adductor field. The bounding median lobes of the diductor scar practically enclose the adductor field anteriorly, except for a narrow groove which produces a median notch in

the otherwise straight anterior edge of the muscle field. The antero-lateral angles of the median diductor lobes are almost 90°, giving a squarish appearance to the front of the scar. Outside these are the lateral lobes of the diductor scars, whose convex outside margins give a rounded aspect to the whole scar when strongly developed. These are the adjustor scars of authors (Schuchert & Cooper 1932, e.g. pl. A, figs. 12, 13 ; Moore, Lalicker & Fischer 1952 : 208, text-figs. 6–10) ; the adjustor scars are however found immediately outside these on the inner surface of the dental lamellae, and there seems little doubt that the disposition of the scars is similar to that of the closely related dalmanellid stocks, rather than to that of the Recent terebratuloids (see Williams & Wright 1963 : 16).

As may be expected from the development of a sulcus, the costellae of the ventral valve are more commonly internal than external, although both do occur ; where a costella arises on either side of a costa, the tendency is for the internal one to arise first.

Rib counts on the ventral valves show 16–21 primary costae on 2, 0, 2, 0, 1, 3 valves, other estimates where the ribbing was partly obliterated also falling within this range and suggesting a modal number of about 19. The wavelength of the median rib was measured at 5 and 10 mm., but the figures vary greatly according to the position of splitting of the ribs. Thus for rib density a more satisfactory picture is obtained from a count of the number of ribs per 2 mm. measured medianly at 5 mm. from the ventral umbo ; the sample shows 2–5 ribs present on 1, 9, 5, 1 shells.

The total number of ribs was counted at three growth stages ; at 5 mm. 20–35 ribs are present on 1, 0, 1, 0, 0, 1, 1, 1, 3, 0, 1, 1, 1, 1, 0, 1 valves, which in spite of the large scatter in the 13 shells shows a distinct mode of about 28 ribs ; at 10 mm. 36–48 ribs are present on 1, 1, 2, 0, 0, 1, 1, 1, 0, 0, 0, 0, 1 valves ; at 15 mm. 45, 50, 51, 54, 57 ribs are present on 5 valves ; whilst one complete fairly large shell (length 24 mm.) has 70 ribs at its margin.

A rib count taken on the dorsal valves at 7·5 mm. from the umbo shows 26, 27, 29, 30, 32, 32, 34 ribs present on 7 valves.

Statistical data on shell outline and profile are rather sparse due to the broken nature of the valves, especially the dorsal valve, the large size of this species rendering it very susceptible to damage. In a sample of 8 ventral valves, the mean valve length : width % is 72·9 (var. 138·7) ; four valves show the thickness : length ratio to be 22, 23, 24 and 27%.

A sample of 8 ventral valves have a mean % for the length of the interarea : valve length of 19·5% (var. 2·57) ; the length of the interarea relative to its width in 4 valves is 17, 17, 19 ,22% ; whilst 3 valves have identical figures of 81% for the ratio of the width of the interarea : maximum valve width.

The original description of *Orthis porcata* by M'Coy (1846 : 32) was based solely on material from Portrane, and his figure of a broken ventral valve (pl. 3, fig. 14) shows the typical ribbing pattern of the species. In M'Coy's later description of the species (1852 : 223), he figured specimens from the Coniston Limestone (pl. 1, H, figs. 41, 42) and cited some ten localities at which the form occurs. However, it

is quite certain that *P. porcata* does not occur at all of these localities ; it is not present for example in " the Caradoc Limestone of Horderly S.", which is presumably the Alternata Limestone.

Nevertheless it does appear to be a widespread form in the British Ashgillian rocks, for apart from actual descriptions of the species (Davidson 1870 : 251 ; Reed 1917 : 840) there are many records of its occurrence in rocks of Ashgillian and even of Llandoverian age (Groom & Lake 1908 : 578).

In spite of the fragmentary nature of the Portrane shells, already mentioned by M'Coy (1852 : 223), it is hoped that the current re-description of this topotypic material will prove useful for comparison with specimens from other localities ; thus the validity or otherwise of the various records of the form can be established.

Family **DOLERORTHIDAE** Öpik 1934

Genus ***DOLERORTHIS*** Schuchert & Cooper

Dolerorthis inaequicostata sp. nov.

(Pl. 3, figs. 17, 21, 23, 25–27)

Diagnosis. Subequally biconvex *Dolerorthis* of transversely subquadrate outline with rectangular to slightly obtuse cardinal angles ; margins slightly rounded postero-laterally and anteriorly, strongly rounded antero-laterally. Ventral valve about three-quarters as long as wide, thickness ranging from one-quarter to one-third of valve length ; lateral profile with maximum depth and convexity at about one-quarter of shell length, less convex anteriorly. Anterior profile usually evenly convex. Interarea curved, apsacline, with length about one-fifth of its width and of valve length ; delthyrium rather narrow. Dorsal valve about two-thirds as long as wide and over one-quarter as deep as long ; evenly convex in lateral profile ; convex in anterior profile, but divided medianly by well-developed sulcus ; interarea flat, anacline, about one-ninth as long as valve, notothyrium open. Ornamentation costellate, usually with 3 ribs per mm. at the 10 mm. growth stage, crossed by poorly preserved concentric growth lamellae with a density of about 3 per mm. at 5 mm. anterior to dorsal umbo. About 16 primary costae at dorsal umbo, with up to 3 additional costae along hinge-line on either side, ribs having a rounded crest and subparallel sides. 18–20 costae present at the 3 mm. growth stage ; only one generation of costellae, with four-fifths of the internal ones, but only about one-fifth of the external ones, developed by the 5 mm. growth stage. Costellae remain less pronounced than the costae. Sulcus occupied by 4 primary costae. Ventral ornamentation with a median rib which develops a costella on either side ; rib 2, sometimes rib 3 and occasionally rib 4 develop an external costella ; rib 5, usually rib 4, and sometimes ribs 3, 6, 7, develop a costella on either side ; ribs 8, 9 and sometimes 6, 7, develop only internal costellae, whilst ribs outside these remain simple costae. Ventral costellae arise somewhat later than the dorsal, thus at the 5 mm. growth stage there are seldom more than the 20 costae developed. At 10 mm., a total of 43 ribs were recorded for one valve.

Ventral interior with strong teeth and receding dental lamellae ; muscle field

cordate, about four-fifths as wide as long and about two-fifths as long as valve ; adductor scars narrow (one-fifth as wide as whole scar) situated on slight ridge, and about nine-tenths as long as diductor scars. Dorsal interior with simple cardinal process on notothyrial platform, anterior to which is a short low median ridge ; brachiophores short blades, grooved on the inside and triangular in cross section.

		Length	Width
Holotype.	Dorsal valve (BB.30210) . .	9·6 mm.	13·9 mm.
Paratypes.	Ventral valve (BB.30211) . .	13·8 mm.	c. 17 mm.
	Ventral valve (BB.30212) . .	14·6 mm.	c. 19 mm.
	Ventral valve (BB.30213) . .	12·2 mm.	17·4 mm.
	Broken dorsal valve (BB.30214)	—	—

Discussion. This species of *Dolerorthis* is characterized by the rather transverse outline, the subequal convexities of the valves, the presence of a well defined dorsal sulcus, and the rather late development of a single generation of costellae, which never attain the size of the costae, so that the latter tend to stand out clearly.

Although not many complete specimens of the new species are available, sufficient data has been obtained to carry out a comparison with the subspecies of *D. duftonensis* from the Gelli-grîn calcareous ashes recently erected by Williams (1963 : 357). A small sample of topotypic *D. duftonensis* s.s. from Cross Fell was also examined by Williams, the differences between it and his subspecies *prolixa* being found in the nature of the brachiophores, the relatively longer dorsal valve, shorter dorsal interarea, deeper ventral valve, and shorter ventral muscle field of *D. duftonensis* s.s.

For the outline of the dorsal valve, the length of a single complete Portrane shell was 69% of the width ; although less than the mean (75%) this falls within the range for the Welsh form, which is significantly different from the figures of 74, 77, 85, 86, 90% for five Cross Fell specimens. Five Portrane ventral valves have a mean ratio of thickness : length of 28·8% (var. 17·7) ; the mean for the Welsh shells is very close to this at 28·6%. In a comparison with Williams' three valves of *D. duftonensis* (p. 358), with ratios of 37·5, 44·4 and 50%, the Portrane shells (24, 26, 29, 30, 35%) show a significant difference, P=·018. The length of the dorsal interarea : length of dorsal valve for three Portrane shells is 11, 11 and 12%. For this statistic, the mean for the Welsh shells is 11·9%, and for *D. duftonensis* s.s. 10·4%, these two being significantly different from each other (Williams 1963: 360). Whilst the Portrane valves are closer to the Welsh form, a Rank Sum Test shows that this sample is not significantly different from either. The mean ratio of the length of the ventral interarea : valve length for a sample of 7 Portrane valves is 21% (var. 8·0), no figures being given by Williams for this statistic.

The mean width : length ratio for the ventral muscle scar of 5 Portrane valves is 78·4% (var. 54·5), which is comparable with both subspecies of *D. duftonensis*. However, the length of the ventral muscle field relative to valve length is significantly larger in the Welsh form (26, 29, 31, 32, 35%) than in the English one (24, 26, 26, 27, 29%); a comparison of the Irish shells with Williams' Rank Sum data reveals that the muscle field of the Irish form (35, 36, 38, 39, 43%) is significantly longer than either (P=·008).

This last is really a reflection of the shorter, more transverse nature of the Portrane shells which cannot be adequately brought out by the solitary complete dorsal valve (see above) ; Williams gives no data on the length : width of the ventral valve, but his two ventral paratypes show ratios of 91, 93% in contrast to ratios of only 70 and 81% for two complete Portrane valves. Approximations for four partially damaged Portrane valves also fall within this range, so while it seems fairly certain that the Portrane valves are more transverse than the other forms, the accurately measured samples are too small to confirm this mathematically. Again, the single perfect dorsal valve shows a thickness : length ratio of 27%, compared with a mean of 17% for the two sub-species of *D. duftonensis*.

Reed (1910 : 295) described the dorsal valve of *D. duftonensis*, which is shallower than the ventral, as having a " faint median longitudinal depression occasionally present ". Williams (1962 : 115), in placing some specimens from Craighead as *Dolerorthis* cf. *duftonensis*, states that these shells differ from *D. rankini* in the absence of a strong dorsal median sulcus ; and in describing *D. duftonensis prolixa* from the Bala district, he states that species to be " gently sulcate medianly but evenly convex in longitudinal and lateral profile " (1963 : 357).

The strong sulcus of the Portrane dorsal valves, which produces a pronounced saddle in the anterior profile, is a marked difference between it and the *duftonensis* stock.

The ornamentation of the two stocks differs in several ways. The costae of the Portrane shells are much more prominent than the costellae, whilst the two are of equal strength in *D. duftonensis* s.l. In the ventral valve figured by Williams (1963, pl. 2, fig. 8) the right flank shows the median costa with a costella on either side, the other costellae being 2a°, 3a°, 4a°, 5a°, 6a°, and 7a⁻, 9a⁻, 10a⁻; whilst a sample of eight Portrane valves (three of which have the ribs outside 6 obliterated) show costae 2, 3, 4 to have a single external costella 8/8, 4/8, 2/8 times ; both an internal and external costella on costae 3–8, 4/8, 6/8, 8/8, 4/7, 2/4, 1/4 times ; and a single internal costella on costae 6–9, 3/7, 2/4, 3/4, 3/3 times, respectively.

Thus while the inner ribs possess external and the outer ribs internal costellae in both forms, the double costellae of the intermediate sectors are missing in the Bala shell, at least in the type.

The Portrane valves have 16 or 17 primary ribs at the umbo with up to 3 additional ribs on either side, whilst the Bala type ventral valve shows 30 primaries, the difference being due in part to the large number developing laterally along the hinge-line. The Bala shell has about 24 ribs at the 3 mm. growth stage, compared with 19, 19, 19, 20 in 4 Portrane shells ; at 5 mm. it has 34 compared with 19, 20, 23 for 3 Portrane specimens, and at 10 mm. 50 ribs compared with 43 for a Portrane shell.

Thus although the total number of ribs is not very different, the method by which they arise is different. To summarise, the Portrane ventral valves (a) have fewer costae, with less along the length of the hinge ; (b) these persist for a greater valve length before branching, and as a result are strong costae ; and (c) the costae which are intermediate in position produce a costella on either side.

The earlier development of costellae is also seen in the dorsal valve of the Bala shells, where the 2 specimens measured by Williams (raw data) show that the early $3a^-$ is already developed by the 2 mm. growth stage in both valves, with $4a^-$ and $9a^-$ also developed in one of them ; this very early development is apparently typical (Williams, personal communication). On the other hand at the 3 mm. stage only one out of 7 Portrane shells had an internal rib developed ; this was a $3a^-$, although this rib is by no means as consistently early or the $2a^-$ as consistently late as in the Bala form, the data on rib development being given in Table 4.

TABLE 4

$2a^-$) $3a^-$	3/5 (1)
$3a^-$) $4a^-$	3/5 (2)
$4a^-$) $5a^-$	2/3 (4)
$2a^-$) $5a^-$	4/5 (1)
$2a^-$) $4a^-$	3/5 (2)

TABLE 4. Frequencies of relative dorsal rib development in a small sample of *Dolerorthis inaequicostata* sp. nov., figures in parentheses indicating the frequencies where the costellae arise at an equal distance from the umbo.

The actual costellae developed have a similar distribution to those of the Bala shell ; as regards rib density, at the 10 mm. growth stage the ribs measured medianly over a 2 mm. distance for the Portrane shell were 3, 3, 3, 3, 4 in 5 valves. Williams' Bala shells showed 1 and 2 ribs per mm. on 1 and 7 valves measured in the same position ; in the case of the Portrane valves " one and a half ribs " per mm. was not very satisfactory, thus the count was taken over 2 mm. These figures suggest a rather coarser ribbing in the Portrane shells.

Thus, whilst the Portrane species shows features which are very similar to those of the *D. duftonensis* stock, more particularly to the Bala subspecies, it does differ, principally in the presence of a dorsal sulcus, the subequal convexity of the valves (which are more transverse), the relatively longer ventral muscle field, the uneven size of the costae and costellae, and other features of the ornamentation as indicated above.

D. rankini (Davidson) from the Ardwell Beds, Girvan, resembles the Portrane shell in the presence of a strong dorsal sulcus ; but differs in having a relatively longer dorsal valve, a relatively shorter ventral muscle scar [Williams (1962 : 114) records a mean of 33% of the valve length for this character in 3 valves, the raw data being 33, 33 and 34% ; this shows a significant difference ($P = \cdot 018$) from the Portrane figures in a Rank Sum Test], and almost double the number of much finer ribs (having c. 90 in a valve 15 mm. long). As in the Derfel Limestone species, *D. tenuicostata*, recorded by Whittington & Williams (1955 : 406), costellae are produced by both early and late insertions of secondary ribs and also by tertiaries. The ribs of this last form are also considerably finer and more numerous with the first secondaries arising much earlier than in the Portrane shells, and like *D. rankini* have a less transverse outline ; they also lack the strong sulcus of the Girvan and Portrane shells.

Family **PLECTORTHIDAE** Schuchert & Le Vene 1929

Subfamily **PLECTORTHINAE** Schuchert & Le Vene 1929

Genus ***PLECTORTHIS*** Hall & Clarke 1892

Plectorthis ? ***perditosulcata*** sp. nov.

(Pl. 6, figs. 2–6, 8, 9)

1861 *Orthis calligramma* Dalman ; Baily : 11 (*pars*).
1880 *Orthis calligramma* Dalman ; Baily : 82 (*pars*).
1895 *Orthis calligramma* Dalman ; Sollas : 101 (*pars*).

Diagnosis. Ventri-biconvex shells of roundedly subquadrate outline, about four-fifths as long as wide, maximum width near mid-valve. Ventral valve about one-third as deep as long, maximum depth at the umbo ; lateral profile gently convex, anterior profile arched medianly, with rather flat flanks. Interarea about one-third as long as valve, with ratio of length to width approaching one-third ; curved umbonally, but flat over most of its length, varying from strongly apsacline to catacline. Delthyrium with small convex plate occasionally developed at apex. Dorsal valve flatly convex, usually less than one-sixth as deep as long ; median sulcus well developed at the umbo, broadening and becoming lost anteriorly by about 10 mm. or less, when the valve develops an evenly convex surface, but not a fold. Sulcus separated by elevated flanks from flat cardinal regions. Interarea flat, anacline, about one-seventh of valve length. Ornamentation of costae, square in section with rounded crests, separated by flat interspaces on which strong growth lines are preserved. Costellae also present, but of restricted distribution ; dorsal valve with single external secondary rib developed almost invariably in sectors 3, 4, less commonly in sectors 2, 5, and only occasionally in sector 6 ; only one tertiary ($4a^{-}1^{-}$) recorded in 13 valves. Ventral valve with median rib initially stronger than rib 2, external costellae corresponding to internal ones of dorsal valve, with internal rib also appearing rarely. In the dorsal valve, first costella arises at about 3 mm., but may appear over a range of from 1·5 to 6 mm. from the umbo ; 20–26, most commonly 24, ribs at the 3 mm. growth stage ; 23–30, most commonly 28, at the 5 mm. growth stage, with maximum of 34 recorded for any valve. Mean rib wavelength for 10 dorsal valves of 1·0 (var. 0·005) mm. at the 10 mm. growth stage.

Ventral interior with obcordate muscle field, larger diductor scars extending beyond narrow adductor scars ; width : length ratio of muscle field variable, 60, 77, and 85% recorded in three valves. Dorsal interior with sockets defined by small fulcral plates ; brachiophores blade-like, triangular in cross-section, supporting plates convergent on to a variably thickened notothyrial floor which bears simple, plate-like cardinal process. A low, rounded median ridge extends anteriorly from notothyrial platform to divide poorly delimited adductor field.

		Length	Width
Holotype.	Ventral valve (BB.30215) .	14·8 mm.	18·6 mm.
Paratypes.	Dorsal valve (BB.30216) .	c.15 mm.	c.17 mm.
	Incomplete dorsal valve (BB.30217) . . .	18·6 mm.	—
	Ventral fragment (BB.30218) .	—	—
	Ventral fragment (BB.30219) .	—	—
	Imperfect ventral valve (BB.30220) . . .	8·6 mm.	—

Discussion. This new species is placed with some reservation in the genus *Plectorthis*, due to the fact that an occasional ventral valve possesses a small convex plate in the apex of the delthyrium (Pl. 6, figs. 5, 8), a feature at present unknown in *Plectorthis*, but which is characteristic of the plectorthid genus *Desmorthis*.

Desmorthis has only been recorded from the Upper Pogonip Formation in Nevada, and the Joins Formation in Virginia (Ulrich & Cooper 1936 : 624 ; Cooper 1956 : 447) both of Lower Llanvirn age (Twenhofel *et al.* 1954 : 260). Ulrich & Cooper (1938 : 158) also cited the simple thin cardinal process as differentiating their primitive genus from the later, more advanced *Plectorthis*, whose cardinal process possesses a myophore. The crenulated myophore of *Plectorthis* is not, however, as invariable a feature as it would appear from Schuchert & Cooper's discussion of the genus (1932 : 59), for *P. compacta* Cooper and *P. scotica* (M'Coy) possess a simple plate-like cardinal process, as does *P. ? perditosulcata*. The median thickening in the dorsal valve, and the usually well defined anterior margin of the diductor scars in the Portrane species, tend to militate against inclusion with *Desmorthis*. The exact systematic valve of the " deltidium " at this stage in the evolution of the plectorthids is difficult to ascertain, but in view of the large disparity in time between these Upper Ordovician forms, and the known *Desmorthis* species, it seems better for the present to regard the Portrane shells as being closer to *Plectorthis*, with the occasional occurrence of a " deltidium " most probably representing a late morphological convergence towards an ancestral stock. Unfortunately most of the material is fragmentary, with many broken delthyria and others which are caked with silica (as in the holotype), so that the frequency of occurrence of the feature cannot be established with accuracy.

Of the two described species of *Desmorthis*, the Portrane shell more closely resembles *D. costata* Cooper, which, although it is much smaller than *P. ? perditosulcata*, has a similar outline and quantity of ribs. It differs in lacking the characteristic pattern of the Portrane costellae development ; further, costellation takes place very close to the umbo, the actual style of branching not being very clear on the umbo of the type specimen. (Cooper 1956 ; pl. 50, J, figs. 45, 46).

The ornamentation of the Portrane valves immediately distinguishes them from, on the one hand, those species of *Plectorthis* which have costellae arising in virtually all rib sectors, as in *P. magna* from the Percé Formation (Cooper & Kindle 1936 : 352), and on the other, those species whose ornamentation is composed of simple costae, e.g. *P. obesa* Cooper. Other important features are the flatly convex dorsal

valve with the sulcus becoming lost anteriorly, and the comparatively strongly convex ventral valve, whose greatest depth is located umbonally. These features combine to distinguish the species from the American forms of Trenton and later age, the closest species to the Portrane form being *P. lebanonensis* Cooper, from the pre-Trenton Lebanon Formation of Tennessee. This resembles the Portrane species in outline and profile, and in the overall rib pattern. There are some differences in the ribbing however in that the costellae arise earlier, the 30 ribs already being developed by the 3 mm. stage. Moreover, there are fewer costae and more costellae, a costella being produced on sectors 3–8, with rib 1 developed late, or alternatively a costella on ribs 1–7 with an internal rib on rib 1 also, the exact relations of the middle section not being very certain from Cooper's figure of the dorsal valve (1956, pl. 81, D, fig. 15). Apart from these ribbing differences, the Tennessee form also differs in having a sulcus which extends to the anterior margin, and in possessing fine elevated threads in the inter-spaces between the ribs. These last are missing in the Lower Trenton *P. pennsylvanica* which, like *P. ? perditosulcata*, has strong concentric fila in the interspaces. This species again shows early branching on the dorsal valve which is dichotomous and not internal. It also differs from the Portrane shells in having the maximum convexity of the ventral valve at about mid-valve as well as in the presence of a persistent sulcus.

Cooper (1956 : 144) states that the genus is " not certainly known in Europe but widely identified ". Of the British shells that do belong to this genus, *P. scotica*, first described by M'Coy (1852 : 232) is quite distinct from the Portrane species in its strongly biconvex profile, and the neanic dichotomous branching of its more numerous ribs. Williams (1962 : 122) recorded two valves from the Stinchar Limestone which appear to be conspecific with *P. australis* Cooper. These again show little resemblance to the Portrane shells, being ornamented by three generations of very much finer and more numerous ribs.

As Schuchert & Cooper have already remarked (1932 : 59) none of the shells ascribed by Reed (1917) to *Plectorthis* actually belongs to this genus.

The specimens from Portrane leave much to be desired, but the following rather meagre statistical data were obtained and are included for comparative purposes :

(1) Length of ventral interarea : length of ventral valve—25, 32, 33, 34, 35% for 5 specimens.

(2) Length : width of ventral interarea—26, 29, 30, 33%.

(3) Ornamentation of dorsal valve—(a) at 3 mm. growth stage, 20–26 ribs developed on 1, 0, 1, 2, 2, 1, 1 valves respectively.
   (b) At 5 mm. growth stage, 23–30 ribs developed on 1, 1, 0, 0, 1, 3, 0, 1 valves respectively.
   (c) In counts on 21 dorsal flanks (13 left, 8 right) the frequency of the costellae was as follows : $4a^{-}$ (21), $3a^{-}$ (20), $5a^{-}$ (9), $2a^{-}$ (6), $6a^{-}$ (2), $4a^{-}1^{-}$ (1).

(4) Total number of ribs on complete valves, ventral and dorsal, was 26–34 on 1, 0, 4, 0, 1, 2, 0, 1, 1 valves respectively.

Plectorthis sp.

(Pl. 5, figs. 20, 21)

One dorsal valve (BB.30221) differs markedly from *Plectorthis? perditosulcata* in being quite strongly convex, not possessing an initial sulcus and in having a coarse costate ornamentation.

The valve is somewhat damaged, about 15 mm. long, of transversely elliptical outline, with 21–22 simple costae which have somewhat inclined sides and a rounded crest, the flat interspaces being of similar size to the ribs. At 7·5 mm. from the umbo a rib density of 4 in 4 mm. was recorded. Outline subrounded, with hingeline much less than maximum valve width, this being almost at mid-valve. Lateral profile evenly convex ; interarea short, orthocline.

Internally the valve possesses a pair of long blade-like brachiophores joined posteriorly by short convergent plates to the thickened notothyrial platform ; cardinal process ridge-like, possibly with a myophore at the posterior end which is damaged. Fulcral plates well developed ; median ridge short, less than 2 mm.

Discussion. The convexity of the dorsal valve is typical of Öpik's genus *Boreadorthis* and both radial and fine concentric ornamentation are virtually identical with his species *B. crassa* (1934 : 186) which typically possesses 18–21 ribs. The cardinalia of Öpik's species has similar brachiophores and cardinal process (p. 185, text-fig. 43) to the Portrane valve ; but it apparently lacks the fulcral plates of the latter, although the figure is not clear on this point. No mention is made of fulcral plates in the text however, and as the species is placed in the Hesperorthinae and not the Plectorthinae it would appear that they are absent. The Estonian valves do differ in outline from the Portrane shell, in having a much wider hinge line which usually forms the maximum valve width. The costate species of *Plectorthis* described by Roy (1941 : 85), *P. inaequiconvexa*, differs in having a shallower dorsal valve and a greater number of ribs. Both *P. plicatella*, originally described by Hall (1847 : 122) and its variety *trentonensis* erected by Foerste (1910 : 49) for the costate forms, as typified by the Galena shale specimens figured by Winchell & Schuchert (1897, pl. 33, figs. 5–7), usually have more ribs and are very much more transverse than the Portrane specimen, whose outline is closer to the older Middle Ordovician species like *P. australis* and *P. compacta*. However, the 10 or so forms of this age described by Cooper (1956) are all ornamented by larger numbers of ribs.

Genus ***HEBERTELLA*** Hall & Clarke 1892

Hebertella sp.

(Pl. 5, figs. 24, 25)

This genus is only represented in the Portrane material by a single ventral valve, and possibly a dorsal valve.

Description. Ventral valve of (?) subelliptical outline ; profile moderately convex, flattening anteriorly in lateral profile and gently arched medianly in anterior

profile. Interarea curved, apsacline ; delthyrium open. Ornamentation multicostellate. Interior with strong teeth supported by strong dental plates, continuing anteriorly as low ridges to define the muscle field. Muscle field somewhat suboval, slightly longer than wide, with the maximum width at the front of the dental plates ; edges of diductor scars almost straight and narrowing anterior to this point ; narrowly rounded in front but not enclosing the adductor scars ; adductor scars elongate, situated on a double median ridge, which has a shallow groove medianly along its length. A pair of *vascula media* rise at the anterior ends of the diductor scars.

Discussion. Apart from the ventral valve described above (BB.30222), a poorly preserved dorsal valve (BB.30223) is also tentatively placed in this genus. This dorsal valve is of subelliptical outline with evenly convex anterior and lateral profiles. The anterior commissure is gently plicate ; the ornament, although poorly preserved, is similar to that of the ventral valve. Unfortunately, the internal structures are completely obliterated by siliceous material, making absolute identification impossible.

The ventral valve clearly belongs to the genus *Hebertella* in the majority of its features, although the overall shape of the scar, with the lateral edges convergent immediately anterior to the dental plates, is more reminiscent of some species of *Doleroides* than the type species of *Hebertella*, *H. sinuata* (Hall), in which the scar continues to expand for some distance beyond the dental plates (see Schuchert & Cooper 1932, pl. 11, fig. 24). There is, however, considerable variation of this feature within *Doleroides* species (see Cooper 1956, pl. 92 *et seq.*) ; the presence of the double median adductor ridge clearly separates the Portrane *Hebertella* from *Doleroides*, the scar outline being a specific character of the Portrane shell. The Portrane occurrence is the first definite record of the genus from Western Europe, but the material is at present insufficient for identification at specific level.

Genus ***SCHIZOPHORELLA*** Reed 1917

Schizophorella fallax (Salter) ***silicis*** subsp. nov.

(Pl. 5, figs. 9, 13–19, 22, 23 ; Pl. 6, fig. 1)

Diagnosis. Dorsi-biconvex shells, outline varying from rounded to transversely elliptical ; cardinal angles obtuse, rounded, hinge-line width about three-quarters of maximum valve width. Ventral valve about four-fifths as long as wide, and about one third as deep as long ; interarea curved, apsacline, about one-fifth as long as wide, and one-fifth as long as valve ; delthyrium open, anterior profile evenly convex or slightly indented medianly by smoothly rounded sulcus, which passes evenly into the convex flanks, originating at about 7 mm. anterior to umbo (which may be excavated). Anteriorly the sulcus forms a median tongue which projects dorsally to varying extent ; lateral profile of valve accordingly with greatest depth towards posterior.

Dorsal valve about two-thirds as long as wide and two-fifths as deep as long,

evenly convex in lateral profile ; anterior profile swollen medianly due to rounded fold originating at about 8 mm. from umbo, normally remaining low whilst often producing a strongly developed plication in anterior commissure. Interarea flat or only slightly curved, normally orthocline, up to about one-tenth as long as valve ; notothyrium open. Ornamentation of fine, rounded to subangular costae and costellae with occasional strongly marked concentric growth stages. Density of radial ornamentation between 4 and 6 ribs per 2 mm. measured 5 mm. antero-medianly to ventral umbo, the total number of ribs at 10 mm. from the umbo being about 50–60.

Ventral interior with teeth supported by strong dental lamellae, advancing as high ridges to mark outside of elongate muscle field, which is about half as wide as long and about half as long as valve. Muscle field comprises a variably developed pedicle callist umbonally ; a narrow lanceolate adductor scar situated on a median ridge which increases in stature to the front of scar. On either side is a pair of elongate median diductor lobes, whilst lateral diductor lobes are situated off the valve floor on parts of dental lamellae adjacent to median lobes. Anterior of muscle field may be slightly indented medianly where median diductor lobes extend beyond adductor ridge. On valve floor in front of the latter is a low ridge which soon forks ; these features mark the position of the *vascula media*, which then curve round postero-laterally in an arc to surround the large, well marked scars of saccate gonocoeles.

Dorsal interior with low notothyrial platform on which is situated a swollen, ventrally grooved cardinal process. Anterior to platform a strong median ridge develops, rising abruptly, then falling to pass into valve floor by mid-valve. Brachiophores strong, blade-like, deep (being about half as deep as long), in section flattish or slightly sinuate with groove on the inside ; supported posteriorly by convergent plates which pass into notothyrial platform. Sockets defined by small fulcral plates. Smooth, poorly delimited subquadrate muscle field divided longitudinally by median ridge, with posterior adductor pair slightly larger than anterior pair ; gonocoeles strongly impressed lateral to muscle scars, and pair of *vascula media* developed anterior to scars.

		Length	Width
Holotype.	Ventral valve (BB.30224) .	*15·3	c. 21 mm.
Paratypes.	Dorsal valve (BB.30225) .	16·3 mm.	22·9 mm.
	Ventral valve (BB.30226) .	*14·4 mm.	15·4 mm.
	Broken dorsal valve (BB.30227) . . .	—	—
	Deformed ventral valve (BB.30228) . . .	—	—
	Broken ventral valve (BB.30229) . . .	—	19·7 mm.
	Damaged ventral valve (BB.30230) . . .	—	—

* Ventral commissural length (see Text-fig. 1)

Discussion. The new subspecies is distinguished from *S. fallax* principally by the narrower and more elongate ventral muscle field ; and to a lesser extent by the stronger median ridge of the dorsal valve.

The Portrane sample consists of 39 ventral and 35 dorsal valves ; but the nature of the preservation of these specimens is such that only meagre statistical data could be obtained for comparison with the other recorded specimens of *S. fallax*. Further, the illustrations of earlier authors are not always of value in building up data on the specific characters ; the valves ascribed to this species from the Upper Ordovician Hovin Sandstone of the Trondheim area by Reed (1932, pl. 18, figs. 3–5) may be cited as an example.

The measurement of the length of the ventral valves in the Portrane shells used in the data was taken in the plane of the commissure : due to the development of a median tongue the maximum valve length is usually in excess of this (see Text-fig. 1). For valve outline, the length : width % for five ventral valves on which measurements were possible show a mean of 82·8% (var. 76·75) ; four dorsal valves which average 64% for this character show a range of 46 to 82%. Thus while Salter's figures of a dorsal valve from Pomeroy (1846, pl. 5, fig. 3*a*) falls within the range for the Portrane shells, his ventral valve (fig. 3*b*) is more transverse ; no significance can be attached to this however.

The thickness : length % in four Portrane ventral valves is 28, 29, 31, 37% ; and in four dorsal valves 31, 34, 41 and 53%. The mean length : width % of the interareas of six ventral valves is 22·2% (var. 5·0), with a mean length of interarea : valve length of 21·75% (var. 0·9) in four valves ; the length of interarea : length of valve in three dorsal valves is 7, 9, and 10%.

The full data for the ventral muscle field is given below (p. 201) ; the mean width : length ratio is 49%, with a range of 36–62%. A comparison with the scars of other figured specimens shows that of the new subspecies to be relatively longer and narrower. As the majority of figures available are internal casts, the measurements obtained from them for the width of the scar are less than the true width of the scar. This is because the scars extend across the lower parts of the dental plates ; these diverge away from the floor of the valve, so that their tops are not visible on the internal moulds. Salter's figure 3*b* gives a width : length ratio of 67% ; Reed's figures 19 and 24 (1917, pl. 10) of specimens from the Upper Drummuck at Girvan are conservatively estimated at 60 and 64% respectively ; while Schuchert & Cooper figure an internal mould with a ratio of about 67% (1932, pl. 12, fig. 1). A cast taken from this last (pl. 12, fig. 9) shows a ratio of about 76%, some of the shortening being due to the tilted attitude of the specimen. These values, although, as stated, underestimated for the moulds, are still higher than the figures for the Portrane subspecies, indicating the narrower nature of the scar in the latter.

The other feature by which the new subspecies can be distinguished from the Pomeroy and Girvan shells is the dorsal median septum, which is generally much stronger in the Portrane shells. In two complete shells it extends for 40 and 52% of the valve length.

No differences were established between the new subspecies and *S. fallax* s.s. as

regards shell shape or ornamentation. Three Portrane ventral valves showed a total of 48, 54 and 61 ribs at 10 mm. from the umbo ; a dorsal valve also showed 61 ribs at this distance, whilst at 5 mm., two valves showed 28 and 32 ribs. The numbers of ribs per 2 mm. medianly at 5 mm. from the ventral umbo were 4, 4, 5, 6, 6 on five valves.

Apart from *Orthis mullochensis*, which was originally placed in the genus by Reed (1917 : 859) but was later shown to belong to *Mendacella* (Schuchert & Cooper 1932 : 62), the only other species to be attributed to this genus is the Russian form *Schizophorella kasachstanica*. Amongst the external differences separating this species from the type species are, according to Rukavishnikova (1956 : 120), the transversely elongate shape of the shell, the more convex ventral valve, and the distant nature of the ribbing ; and internally the thicker dental plates and the absence of the short median septum in the dorsal valve. This last point is certainly noteworthy, and an examination of Rukavishnikova's figures suggests that the species does not in fact belong to the genus *Schizophorella*. For whilst Rukavishnikova's figured ventral internal mould (pl. 1, fig. 4*a*) would seem very close to that of Reed's genus, the dorsal internal mould (pl. 1, fig. 4*b*) shows no sign of the convergent supporting plates or of the fulcral plates characteristic of the genus. Although the plate figures are not very clear, the absence of these structures is confirmed from the serial sections figured by Rukavishnikova in Text-fig. 1.

The following statistical data were obtained in a bivariate analysis of the length (l) : width (w) of the ventral muscle scar :—n=11 ; $\bar{l}$ (var. l)=7·02 mm. (2·84) ; $\bar{w}$ (var. w)=3·43 mm. (0·71) ; r=0·821 ; a (var. a)=0·4994 (0·00903).

Genus ***SCAPHORTHIS*** Cooper 1956

Scaphorthis sulcata sp. nov.

(Pl. 8, figs. 3, 4, 8–10, 13)

Diagnosis. Transverse ventri-biconvex shells, of roundedly subrectangular to almost semicircular outline. Cardinal angles slightly obtuse, with maximum valve width varying in position from just anterior to hinge-line to about mid-valve ; hinge-line width over four-fifths of maximum valve width. Ventral valve almost half as deep as long, evenly convex in anterior profile, with no tendency for peripheral flattening, and only a suggestion of a fold ; convexity of lateral profile more pronounced near umbo. Interarea curved, apsacline, about one-fifth as long as valve, and slightly less than one-fifth as long as wide ; delthyrium open. Dorsal valve gently convex, with wide shallow sulcus developing medianly immediately anterior to convex umbo, separated by convex areas on either side from the flattened postero-lateral regions. Interarea very short, flat, anacline ; notothyrium small, occupied by myophore. Ornamentation of costae and costellae, together with very pronounced growth lines at intervals of about 0·1 mm., producing a reticulate appearance. Median rib of ventral valve prominent in young stages. Margins of

dorsal sulcus formed by costa 3, sulcus usually containing 6 or 8 ribs at the 2 mm. growth stage ; rib density of 3–5 ribs per mm. at this growth stage.

Ventral interior with teeth supported by weak, receding dental lamellae ; poorly defined muscle field small, triangular, somewhat longer than wide ; pedicle callist present. Dorsal cardinalia about half as long as wide approaching one-third of valve length in young stages but becoming relatively shorter in larger valves. Cardinal process slender, clearly differentiated into myophore and shaft. Brachiophores short, blunt, with supporting plates convergent on to median ridge ; sockets defined by small fulcral plates. Median ridge simply an internal expression of sulcus, without additional thickening. Muscle field and pallial markings poorly preserved.

		Length	Width
Holotype.	Ventral valve (BB.30258) .	6·4 mm.	8·3 mm.
Paratypes.	Damaged ventral valve (BB.30259) . . .	c. 7·0 mm.	9·1 mm.
	Dorsal valve (BB.30260). .	c. 3·5 mm.	5·1 mm.
	Broken dorsal valve (BB.30261)	5·0 mm.	—
	Broken dorsal valve (BB.30262)	7·3 mm.	—
	Unfigured damaged dorsal valve (BB.30263) . .	5·1 mm.	6·7 mm.

Discussion. The new species is placed in the genus *Scaphorthis* on the assumption that it possesses an impunctate shell. There is, however, a little uncertainty over this point, as amongst the sample of about 30 shells there is a single specimen (BB.30263) which appears to be endopunctate when the inside of the shell is moistened ; it seems more likely that the dark spots are in fact produced by particles of mud in the external " pits ", formed by the fine reticulation of the marked growth lines with the radial ornament. Further, the " punctation " is by no means as definite as that seen in the figured specimen of *Laticrura* (Pl. 11, fig. 19) which takes the form of very clear pitting on the inside of the shell ; this preservation is rather exceptional, for no punctation has been observed in the other associated endopunctate stocks such as *Dicoelosia* and *Dalmanella*. The punctation of the shell of *S. sulcata* is then rather unlikely although this point cannot be completely resolved until sections have been taken from specimens preserved in the form of calcareous shells.

In the dalmanelloid appearance of the shell and the style of the cardinalia the species is similar to the plectorthid genera *Corineorthis* and *Giraldiella* as well as *Scaphorthis*. The convexity of the ventral valve separates the Portrane shells from *Corineorthis*, which possesses a concave ventral valve (Stubblefield 1939 : 67), and from *Giraldiella* in which the dorsal valve is more convex (Williams 1951 : 91). Species of the latter genus also differ in having an undifferentiated cardinal process.

The new species is quite distinct from the other species at present ascribed to *Scaphorthis*. The measurements given for these species by Cooper (1956 : 504–506),

converted to percentages, and arranged in ascending order, are compared with the Portrane sample as follows :—

(1) *Length : width of ventral valves.*
S. sulcata, 7 valves—59, 64, 65, 66, 77, 78, 81%.
S. kayi, 4 valves—89?, 91, 91, 92%.
S. perplexa, 3 valves—85, 89, 90%.
S. virginiensis, 4 valves—86, 90, 91, 91%.

Comparison by Rank Sum Test indicates that the Portrane shells are significantly more transverse in all cases (P=·003, ·008, ·003 respectively).

(2) *Hinge-width : valve width.*
S. sulcata, 6 valves—79, 84, 85, 87, 89, 92%.
S. kayi, 4 valves—65, 65, 69, 79?%.
S. perplexa, 4 valves—66, 69, 71, 73%.
S. virginiensis, 6 valves—75, 75, 78, 80, 83, 84%.

Comparison by Rank Sum Test reveals that the hinge-line width relative to the valve width is significantly larger in *S. sulcata* than in the American shells (P=·007, ·005, ·011 respectively).

The new species differs from the American species of *Scaphorthis* also in the development of strong closely-set growth lines which give a reticulation to the shell surface, although it is seldom preserved over the entire shell.

The Portrane dorsal valve is characterized by a wide, well-defined although shallow, sulcus which is more reminiscent of the Llandovery *Giraldiella protensa* (see Williams 1951, pl. 3, fig. 9) than of any of the American species. The mean width of the sulcus measured at 2 mm. anterior to the beak in 9 valves is 2·1 mm. (var. 0·102).

Additional data for the small Portrane samples are as follows. The thickness : length ratios of 4 ventral valves are 40, 44, 44, 45% ; four ventral valves possess interareas whose length : width percentage is 15, 17, 19, 19% and whose lengths relative to the valve lengths are 18, 20, 22, 24%.

A sample of 5 dorsal valves has a mean of 62% (var. 98) for the length : width ratio. Internally, 4 valves show a length : width ratio for the cardinalia of 46, 53, 54, 55% ; and ratios of 19, 20, 28 and 32% for the length of the cardinalia : valve length, the two smaller figures being those of the two larger valves of this sample.

The density of ornament at the 2 mm. growth stage is 3–5 ribs per mm. on 2, 4, 4 dorsal valves respectively. At this growth stage a distribution of 6–10 ribs in the sulcus occurs in 4, 1, 3, 0, 1 valves respectively. The ribs present here are $3a^{-}$, 2, 1 on either side of the median line, variously supplemented by the development of an internal costella on sectors 1 and 2. Details of the order of insertion of the ribs are given in Table 5.

Rib counts on the ventral valve at the 2 mm. growth stage reveal 18, 21, 22, 24, 25 ribs on 5 valves ; and at the 5 mm. growth stage 3 valves possess 39, 41 and 45 ribs.

TABLE 5

Rib relation	Frequency
$2a^{-}$) $3a^{-}$ . . .	0/8 (1)
$2a^{-}$) $4a^{-}$ . . .	1/5
$2a^{-}$) $2a^{\circ}$ . . .	4/4
$3a^{-}$) $3a^{\circ}$ . . .	11/11
$3a^{-}$) $4a^{-}$ . . .	10/10
$3a^{-}$) $4a^{\circ}$ . . .	1/6 (3)
$3a^{-1-a^{-}}$) $2a^{\circ}$ . . .	2/2
$3a^{-1-a^{-}}$) $3a^{\circ}$ . . .	2/2
$4a^{-}$) $4a^{\circ}$ . . .	0/7
$4b^{-}$) $4b^{\circ}$ . . .	0/5

TABLE 5. Table showing the frequencies of relative costella development on dorsal valves of *Scaphorthis sulcata* sp. nov. Figures in parentheses denote the frequency of forms in which the ribs involved arose simultaneously.

Subfamily **RHACTORTHINAE** Williams 1963

Genus ***RHACTORTHIS*** Williams 1963

Rhactorthis sp.

(Pl. 8, figs. 1, 2, 5–7)

DESCRIPTION. Subcircular ventri-biconvex shells possessing a sulcate anterior commissure. Ventral valve about two-fifths as deep as long, evenly convex in lateral profile and slightly carinate in anterior profile ; interarea curved, apsacline, about a quarter as long as wide and a quarter as long as the valve ; delthyrium open. Dorsal valve four-fifths as long as wide and almost one-third as deep as long, evenly convex in lateral profile but grooved medianly in anterior profile by a rather narrow sulcus arising just in front of the umbo ; this becomes broader and shallower towards the front and may be almost lost except as an undulation in the anterior commissure. Dorsal interarea very short, orthocline to slightly apsacline, notothyrium partially filled by the myophore. Ornamentation consisting of hollow costae and costellae, dorsal valve with just over 30 ribs developed at the 3 mm. growth stage, and a density of 3 per mm. at the 5 mm. growth stage ; distinctive concentric ornamentation of strong, irregularly spaced and exaggerated " growth lines ".

Ventral interior with teeth supported by short dental lamellae bounding the postero-lateral sides of the muscle field ; this is sub-triangular in outline, with length and width about equal, and divided into a broad adductor track flanked by slightly longer submedian diductor lobes. Dorsal interior with cardinalia consisting of cardinal process with crenulated myophore and thick shaft which is continuous with a stout median ridge extending to about mid-valve ; adductor field divided longitudinally by the median ridge ; *vascula media* and *vascula myaria* radially arranged.

Figured Specimens	Length	Width
Dorsal valve (BB.30264) . .	5·3 mm.	c. 6 mm.
Dorsal fragment (BB.30265) . .	c. 7·5 mm.	—
Ventral valve, broken marginally (BB.30266)	—	—

Discussion. The Portrane species possesses all the typical characters of Williams' genus (1963 : 371). The Irish shells show much closer affinity to the type species, *Rhactorthis crassa*, than to *R. melmerbyensis* (Reed 1910 : 296), the only other species so far attributed to the genus. Reed's species differs from the Portrane species and *R. crassa* in possessing a strongly carinate ventral valve. The thickness : length ratio is also larger, varying from 42 to 56% in the 3 shells cited by Williams (1963: 375) compared with 37 and 38% for 2 Portrane shells.

The genus is uncommon in the Portrane material, only 7 specimens in varying states of preservation being available for comparison with the type species.

The thickness of the ventral valves is almost identical, although the figure of 30% for thickness relative to valve length for a single Portrane dorsal valve is deeper than the mean of 22·2% (var. 8·2) for 6 Welsh shells. A Portrane dorsal valve shows a length : width ratio of 81% compared with a mean of about 72% for the Welsh sample. This statistic for 3 ventral valves is 76, 83, 91% ; no data are given by Williams for this feature. The length : width of the cardinalia are 48, 50 and 53% in 3 Portrane valves, higher than the mean (c. 41%) for the Welsh valves, as is the length of the cardinalia relative to the valve length (21% in 2 Portrane valves, and a mean of c. 17½% for *R. crassa*).

The density of 3 ribs per mm. at 5 mm. from the dorsal umbo on one Portrane valve is the modal number for the type species. Due to adherent silica, rib counts were not obtained at the 2 mm. growth stage, but at 3 mm., where 31, 32, 33 were counted on three valves.

While the Portrane shells are similar to *R. crassa*, they appear to differ in having a less transverse outline, a deeper dorsal valve and relatively longer cardinalia. However, with the very small amount of data available, the Portrane shells are placed as *Rhactorthis* sp., at least until further material is obtained to ascertain the true significance of these differences.

Subfamily **PLATYSTROPHIINAE** Schuchert & Le Vene 1929

Genus ***PLATYSTROPHIA*** King 1850

Platystrophia lutkevichi Alichova ***contemplata*** subsp. nov.

(Pl. 6, figs. 7, 10–16, 18)

1861 *Orthis biforata* Schlotheim ; Baily : 11 (*pars*).
1880 *Orthis biforata* Schlotheim ; Baily : 82 (*pars*).
1895 *Orthis biforata* Schlotheim ; Sollas : 101 (*pars*).

Diagnosis. Differs from *P. lutkevichi* Alichova, as restricted by Oraspöld (1959 : 54), in having relatively shorter hinge-line and wider sulcus, and attaining larger size, with which is associated the development of additional ribs on the fold and in the sulcus.

Description. Strongly biconvex shells of subquadrate outline ; maximum width at about mid-valve, hinge-line varying from three-fifths to three-quarters of the maximum width. Ventral valve with length (measured in the plane of commissure) ranging from six to nine-tenths of the valve length ; maximum valve length may be up to 10% longer, dependent on convexity ; interarea short, curved, apsacline, about one-ninth of the valve length ; that of the dorsal valve slightly shorter ; curved anacline. Ventral sulcus deep with flattish sides and bottom, maximum width at anterior margin just over half of the valve width ; corresponding dorsal fold prominent, flat-topped. Ornamentation of strong angular costae, with between 6 to 9, most commonly 7 or 8, on each flank at the 5 mm. growth stage ; this may increase to a maximum of 10 at later stages by development of additional costae along the hinge-line. Sulcus with two ribs umbonally, usually increasing by implantation of a rib on each flank and internal branching of the initial pair to produce six ribs in the sulcus of adult valves, with one or two additional ribs appearing in the largest shells. Dorsal fold with three ribs in young stages, normally with external costellae developed on the outer pair, with branching on either side of the median costa in later growth stages.

Ventral interior with moderately strong teeth and strong dental lamellae, advancing to delimit the thickened, elongated suboval muscle field which is about two-fifths of the valve length, with a slightly larger mean for the ratio width : length of the scar itself (for 9 valves the figure is 42·7% (var. 47·4)). Dorsal interior with strong tusk-like brachiophores, small sockets defined by fulcral plates, and a fairly high plate-like cardinal process on the notothyrial floor ; posterior adductor scars smaller than anterior, other details of muscle scars and pallial markings not visible in this material.

		Length	Width
Holotype.	Ventral valve (BB.30231).	17·8 mm.	20·3 mm.
Paratypes.	Ventral valve (BB.30232)	15·4 mm.	25·1 mm.
	Dorsal valve (BB.30233).	c. 20 mm.	22·7 mm.
	Damaged dorsal valve (BB.30234)	—	—
	Dorsal fragment (BB.30235)	—	—
	Ventral fragment (BB.30236)	—	—
	Dorsal fragment (BB.30237)	—	—

Discussion. Since the erection of *Platystrophia* by King (1850 : 106), much has been written on this genus which was of widespread distribution and common occurrence from Middle Ordovician to Middle Silurian times. The first extensive analysis of the genus was carried out by Cumings (1903 : 10), who recognized the three basic subdivisions of uniplicate, biplicate, and triplicate types, currently referred to as the unicostate, bicostate and tricostate groups (Schuchert & Cooper 1932 : 67) ; these group names refer to the numbers of radial ribs in the ventral sulcus at the completion of the early growth stages of the shell.

In the Portrane sample, 1–3 costae are present in the ventral sulcus of 2, 35 and 1 valves respectively at the 5 mm. growth stage. The valve with 3 ribs was a

bicostate form in the younger stages, having a median rib intercalated later. The two specimens with a solitary rib, would, if not found associated with the bicostate shells, be termed unicostate forms and be included in a different species group ; however these appear to be natural variants of the population, for as Cumings says (1903 : 11), " practically any group of *Platystrophia* may produce an occasional uniplicate individual ".

McEwan (1920) elaborated on the basic subdivisions of Cumings and the bicostate group, to which the Portrane shells belong, was divided into four subgroups, again on the basis of rib development on the fold and sulcus (p. 389). Subgroup A possesses two costae in the sulcus and three on the fold ; subgroup B has an extra costa intercalated medianly between the two costae of the sulcus, whilst the median rib of the fold bifurcates ; subgroup C has a costa developed on the lateral slopes of a style A sulcus, whilst the two lateral costae of the fold both bifurcate ; subgroup D is a combination of B and C, so that the sulcus has the basic two costae with the addition of both a median and a pair of lateral ribs, whilst on the fold all three ribs bifurcate. The presence in the Portrane sample of shells showing the typical development of subgroups A, C and D, suggests that, although variability of rib development was known to McEwan, not sufficient consideration was given to this facet in the development of her " pigeon-hole " classification.

The artificial nature of McEwan's classification has also been pointed out by Williams (1962 : 126), after examination of topotype material of some of McEwan's Trenton " species "; again, in a description of the Bala specimens of *Platystrophia* (Williams 1963 : 371) difficulties similar to those appertaining to the Portrane shells were experienced, i.e. what is certainly a homogeneous sample would have to be split into three or more species using McEwan's system of classification.

Many of the Portrane shells are broken anteriorly, so that in most cases it is only possible to determine the number of costae in the sulcus or on the fold at the 5 mm. growth stage ; the figures for the ventral sulcus have been given above, for the dorsal fold 3, 40 valves have 2, 3 costae respectively, the frequency of " unicostate " forms being similar to that found in the ventral valve. At the 10 mm. growth stage, 3 and 4 ribs are present in the ventral sulcus of 5, 4 shells, and at the 15 mm. stage 5 and 6 ribs are present in 1 and 3 valves respectively. One large fragment shows 8 ribs in the sulcus. Of the larger specimens, 8 show the development of a rib on each lateral slope of the sulcus as the first stage of rib increase (subgroup C), although the pair do not always appear simultaneously, and the appearance of the first may vary anywhere from between about 6 and 10 mm. anterior to the umbo. At a later stage (10–14 mm.) 5 of these show the development, again not always symmetrical, of an internal branching of the two initial ribs in the sulcus. In three other shells, a single median rib arises before the development of the lateral pair (subgroup D, but which would also be classified as subgroup B had the shells ceased growing before the appearance of these lateral ribs), in one specimen as an intercalated rib, in the others as the internal branch of one of the initial ribs. In the large fragment mentioned above, the two lateral ribs are the first to develop after the initial pair in the sulcus ; subsequently the right-hand rib of the original pair

branches internally, followed by the appearance of a second pair of lateral ribs at the side of the sulcus, and an internal branching of the first lateral rib on the left-hand side to produce a total of eight ribs in the sulcus at the anterior margin (Pl. 6, fig. 7).

The number of ribs in the sulcus of the Portrane shells depends then to a certain extent on the size attained by the valves ; the pattern is basically bicostate, most frequently of subgroup C style, with the addition of a pair of internal ribs developing from the two initial costae.

The pattern on the dorsal fold is complementary to this ; in three valves the outside pair of the basic three ribs branch externally to produce 5 ribs at the 10 mm. growth stage ; in the specimen which attains 15 mm. in length, 7 ribs are present by that stage, the additional pair arising on either side of the median rib. A single valve resembles the styles of the subgroups B and D, the median rib bifurcating, with an external rib rising on one of the lateral ribs later.

The mean wavelength of the costa immediately lateral to the sulcus on 8 ventral valves at 10 mm. from the umbo is 1·32 mm. (var. 0·0157).

The style of ornamentation of the Portrane valves compares broadly with only four of the many described forms of the genus ; *P. fissicostata* (M'Coy), *P. camerata* Twenhofel, *P. lutkevichi* Alichova and its subspecies *P. lutkevichi satura* Oraspöld.

From M'Coy's description of *P. fissicostata* (1852 : 193), it is evident that his " specific characters " are the summation of characters observed in a large number of what would now be regarded as distinct stocks, and which had as a common theme the general appearance of *P. biforata* with the ribs branching somewhere on the shell. Undoubtedly a large quantity of *Oxoplecia* were present in this material, as well as various Platystrophias of Caradocian and Ashgillian age.

This species is in dire need of reassessment. Of the specific characters given by M'Coy, only the description of the ventral sulcus is of any consequence, and it is from this that the characters of the species must be re-assessed :—" four ribs on the rostral part of the mesial furrow, the two outer of which usually branch at four or five lines from the beak, the others branch irregularly lower down once or twice ". This style of ornamentation is seen in the specimen from Llanfyllin figured by Davidson (1869, pl. 37, fig. 19). The presence of four ribs in the sulcus at an early stage is very similar to *P. camerata*, and quite different from the Portrane shells, where the two initial ribs persist by themselves for some distance to give a totally different appearance to the sulcus. All the characters of the species cannot be assessed from Davidson's figure 19 ; but in the number of ribs on the flanks, the apparently flat-bottomed and sharp-sided sulcus it resembles the Portrane shells, differences being observed in the relatively narrower sulcus, the wider hinge-line (85% of maximum valve width), and the protruding tongue of the sulcus in the Welsh shell (which may be due however to the orientation of the shell).

The only American shell which shows close similarity to the Portrane form is *P. camerata* described by Twenhofel (1928 : 178) from the Ellis Bay Formation of Anticosti. Whilst this is indistinguishable from the Irish shell in many features (e.g. outline, length of hinge), it differs in the following :—(1) The fold is rounded, with the sides passing evenly into the flanks instead of having abrupt margins as

on the folds of the Portrane shells ; (2) For the ratio of maximum width of sulcus : maximum valve width, 41% was obtained from Twenhofel's measurements for a shell, and 44% for his figured specimen, compared with 53, 53 and 55% for three Portrane valves ; (3) While the ribs on the flanks would appear to be similar in number (c. 10), those on the Anticosti shells produce costellae, some of which are developed within the size range of the slightly smaller Portrane shells (see Twenhofel 1928, pl. 15, fig. 13) ; (4) The development of lateral ribs in the sulcus takes place earlier. In the Portrane shells these generally do not appear simultaneously, and although, as stated above, the appearance of the first may vary from about 6 to 10 mm., the mean for seven specimens is 8·6 mm. (var. 2·7) ; and in the specimen where the first rib rises early at 5·9 mm., the one on the opposite side does not appear until 8·8 mm. In Twenhofel's species the lateral ribs appear at " about 7 mm.". From Twenhofel's figure (pl. 15, fig. 15), although this distance cannot be measured, it is evident that the lateral ribs strengthen very quickly, unlike the later laterals of the Portrane shells.

P. lutkevichi was recorded by Alichova (1953 : 26) as coming from the Wesenberg (E) and the Saaremuisa (F1) strata of the Leningrad region. Oraspöld, working on the Estonian Ordovician, found differences between the Platystrophias of the different ages, and erected a new subspecies (1959 : 53) for the specimens occurring in both substages ($F_{1a\alpha}$ and $F_{1a\beta}$) of the Nabala Stage (Männil 1958 : 4). This subspecies differs from the Wesenberg shells in possessing from 12 to 17 ribs on the flanks of the ventral valve, more ribs also on the fold and in the sulcus, and, according to Oraspöld (1959 : 54), in having the width at the posterior margin and at the middle almost equal. This last is in contrast to the Wesenberg shells where the greatest width is at the middle of the shell ; but the figures of both *P. lutkevichi* s.s. (Alichova 1953, pl. 1, figs. 10, 11 ; Oraspöld 1959, pl. 1, figs. 3–5) and *P. lutkevichi satura* (Alichova, pl. 1, figs. 9, 12 ; Oraspöld, pl. 1, figs. 1, 2) show forms which resemble the other subspecies in this respect.

The great number of ribs on the flanks of *P. lutkevichi satura* and on the fold (12) and sulcus (11) at the anterior commissure, also readily distinguishes this subspecies from that of Portrane, as does the very wide hinge-line of the Baltic form (Oraspöld's figures (1959 : 53) give ratios of 90, 93 and 96% compared with 58, 64, 70, 71 and 75% for 5 Portrane shells) and the low nature of its fold in adult shells (Oraspöld 1959, pl. 1, fig. 1*a*).

P. lutkevichi s.s. differs from *P. camerata* and *P. fissicostata* and resembles the Portrane species in the persistence to mid-valve of the two initial ribs of the sulcus by themselves (see Oraspöld 1959, pl. 1, figs. 3, 4), with later ribs of similar pattern which do not attain the size of the earlier ones until the anterior margin (Alichova 1953 : 26). Other similarities to the Portrane valves are found in the range of the ribs developed on the ventral flanks (8–11), the steep-sided fold and the flat-bottomed sulcus. Differences may be seen in the wide hinge, which, although it represents the maximum valve width in some Leningrad forms (Alichova 1953, pl. 1, fig. 10), is only about 79 and 80% for the two complete Estonian valves figured by Oraspöld (1959, pl. 1, figs. 3, 4) ; and also in the narrower sulcus (about 45% of maximum valve width measured anteriorly at its top).

The present writer regards these differences in shape as being of lower taxonomic value than the other features, and accordingly the Portrane shells are placed in *P. lutkevichi*, as a separate subspecies.

Genus ***MCEWANELLA*** Foerste 1920

Mcewanella dorsisulcata sp. nov.

(Pl. 6, figs. 17, 19–21 ; Pl. 7, figs. 1–4)

Diagnosis. Ventri-biconvex shells usually of transverse outline, but showing large variation in shell shape ; hinge-line normally less than maximum valve width, which is located a short distance anterior to it ; cardinal angles usually rounded, obtuse. Ventral valve with median fold ; interarea curved, apsacline, about one-sixth of valve length ; delthyrium open. Dorsal valve with deep median sulcus extending the length of valve and shallowing slightly ; interarea orthocline, flat or very gently curved, half the length of that of ventral valve ; notothyrium open. Ventral valve initially with 7–9 angular costae, basic pattern consisting of median rib flanked by three on either side, with variable occurrence of pair of outside ribs, which curve round to terminate against posterior margin. The other costae usually give rise to single external costella on each between the 3 and 6 mm. growth stages ; between the 7 and 11 mm. growth stages, often after pronounced break in growth, fine costellae develop on earlier ribs. These costellae may or may not be produced simultaneously on all ribs. Dorsal exterior with 8–10 initial costae, most commonly 8, median 2 lying in sulcus ; mean wavelength of costae, measured medianly at 3 mm. from umbo, for a sample of 8 shells is 0·94 mm. (var. 0·034). Strong concentric growth lines and breaks present at irregular intervals.

Ventral interior with strong teeth and dental lamellae continuing anteriorly as ridges to bound the sub-rectangular muscle field, which is about one-third as long as valve, and about two-thirds as wide as long. Adductor scar over one-third of the width of whole scar, usually terminating slightly posterior to diductor scars, with its anterior portion on thickened ridge in older valves. Dorsal cardinalia with cardinal process composed of well-developed myophore and strong shaft ; short brachiophores, curving ventrally to produce tusk-like appearance, with supporting plates which extend vertically to valve floor ; fulcral plates well developed, bounding small sockets, and defining deep crural pits. A pair of low ridges extend anteromedianly from front of supporting plates to meet at almost middle of subquadrate adductor field ; this muscle field with maximum length medianly, half as long as valve, and between half and three-quarters as wide as long.

		Length	Width
Holotype.	Ventral valve (BB.30238) .	14·9 mm.	22·5 mm.
Paratypes.	Ventral valve (BB.30239) .	12·4 mm.	15·4 mm.
	Dorsal valve (BB.30240) .	14·6 mm.	13·0 mm.
	Dorsal valve (BB.30241) .	—	16·4 mm.
	Ventral fragment (BB.30242) .	—	—
	Ventral fragment (BB.30243) .	—	—
	Damaged ventral valve (BB.30244) . . .	c. 15 mm.	—

Discussion. Although some ninety valves of this species have been recovered, they are mostly fragmentary and generally show an inordinate amount of adhering silica. Thus only sparse statistical data were obtained, in spite of the relative abundance of the form. For the shell outline, a sample of 7 ventral valves showed a mean length : width ratio of 71·4% (var. 242·3). This large variation in outline is equally well shown for the dorsal valves, where ratios of 112, 98 and 74% were recorded for three valves. Whilst many specimens show tectonic deformation, both transverse and more elongate shells are present which have not suffered any noticeable post-depositional distortion. The development of costellae is also dependent to a certain extent on shell outline and accordingly also shows considerable variation; e.g. at the 10 mm. growth stage a transverse ventral valve showed 33 ribs, whilst one which was just slightly wider than long possessed only 19 ribs.

Prior to the discovery of this new species, only three species of the genus were known. Of these, two, *M. lineolata* Savage and *M. raymondi* Foerste are North American forms of Richmond and Trenton ages respectively, although there seems to be some doubt over this latter age (Schuchert & Cooper 1932 : 70). The third species, *M. berwynensis*, was described from the Upper Llandeilo beds of North Wales by MacGregor (1961 : 183) ; although this is a much earlier form, it shows a greater affinity to the Portrane species than the American shells in the possession of a dorsal, not ventral, sulcus.

The Portrane shells differ from *M. berwynensis*, however, in having a cardinal process which is composed of a myophore and shaft, unlike the simple ridge of the Welsh species. A simple ridge is more typical too of the American shells, although they do sometimes show a distinct, but rather slender, myophore (Cooper, 1944, pl. 112, fig. 58). Again in contrast to the other species, *M. dorsisulcata* possesses supporting plates which extend vertically to the valve floor, instead of converging to unite beneath the cardinal process.

Externally the dorsal sulcus is much stronger than in *M. berwynensis*, while the two median ribs are, if anything, less prominent than the ones lateral to them. The number of initial costae in the Portrane dorsal valves was 8 to 10, in 8, 2, and 1 shell respectively, the mode being 2 less than the figure given for MacGregor's species (p. 183) ; whilst in the ventral valves 7 to 9 ribs were recorded for 6, 4, and 5 valves, 9 also being recorded for *M. berwynensis*. Later costellae development in the two forms is strikingly different ; for whereas in *M. berwynensis* (MacGregor 1961, pl. 19, figs. 9–15), and also in *M. raymondi* Foerste (1920, pl. 23, fig. 1), the original costae become covered with fine radiating costellae, in the Portrane shells strong " normally branching " external or internal costellae develop, long before the fascicles of costellae so typical of the genus, which generally tend to be slightly coarser and accordingly less numerous than in the other species.

The new species may be most readily recognized by the strong sulcus of the dorsal valve, the style of costellation and the features of the cardinalia.

Family **SKENIDIIDAE** Kozlowski 1929

Genus ***SKENIDIOIDES*** Schuchert & Cooper 1931

Skenidioides cf. ***asteroidea*** (Reed)

(Pl. 7, figs. 5–13)

1917. *Scenidium Lewisi* Davidson, var *asteroidea* Reed: 921, pl. 22, figs. 1-3.

Description. Sub-pentagonal *Skenidioides* with maximum width just anterior to the hinge-line, cardinal angles over 90°. Posterior edges of the valve not parallel to the hinge-line, but forming a straight-sided obtuse angle at the umbo ; laterally and anteriorly the outline is evenly rounded. Ventral valve almost four-fifths as long as wide, and half as deep as long, with only a weakly developed median fold. Anterior profile evenly convex, with a tendency to flatten slightly laterally ; lateral profile variable, from low pyramidal with a gently convex surface to forms of dalmanellid aspect which are quite strongly convex with somewhat incurved beaks. Interarea well developed, about two-fifths of the valve length, curved or flatly apsacline. Dorsal valve flatly to gently convex ; median sulcus broad, evenly and gently rounded. Ornamentation of even, sub-rounded ribs ; ventral fold usually with fascicle of 2–4 ribs by 3 mm. distance from the umbo, a solitary median rib being unusual. External costellae (normally 2a°) also developed by this stage, the total ribs ranging from 12–21. Rib wavelength at the 2 mm. growth stage about one third mm. Dorsal valve with internal costellae, never more than one costella per sector.

Ventral interior with a spondylium over one-third of the valve length. Dorsal cardinalia with simple cardinal process ; sockets bounded by fulcral plates ; brachiophores long, slender, the bases converging on to the median septum at almost one-third of the valve length, the septum itself extending for three-quarters of the valve.

Figured Specimens	Length	Width
Ventral valve (BB.30250) . .	5·5 mm.	6·8 mm.
Dorsal valve (BB.30251) . .	4·2 mm.	5·5 mm.
Dorsal valve (BB.30252) . .	2·9 mm.	4·1 mm.
Ventral valve, damaged marginally (BB.30253)	—	c. 10 mm.
Ventral valve (BB.30254) . .	4·2 mm.	—

Skenidioides paucicostatus sp. nov.

(Pl. 7, figs. 14–20, 22, 25, 27)

Diagnosis. Transverse, alate *Skenidioides* with maximum width along hinge-line ; valve outline with concave posterolateral margin becoming convex antero-laterally, whilst the front may be straight, protruding or embayed. Ventral valve about half as long as wide, and half as deep as long, bearing well-defined median fold ; anterior profile thus strongly convex medianly, lateral profile gently convex, becoming strongly convex anteriorly in some of the older valves (length about

4 mm.). Dorsal valve moderately convex with deep, steep-sided median sulcus. Ornamentation of subangular costae with, in ventral valve, strong median rib whose wavelength at 2 mm. from the beak is almost 0.8 mm., flanked on either side by three smaller but still prominent ribs (wavelength almost 0·5 mm.), outside which may occur from 1–3 fine costae. Median rib occasionally bifurcating ; costellae only exceptionally developed. Dorsal valve with 3 strong ribs on either side of sulcus, usually with finer one lateral to them.

Interior of ventral valve with spondylium which extends about one-third of valve length, only supported by septum posteriorly ; dorsal cardinalia consisting of simple ridge-like cardinal process passing anteriorly into strong median septum. Septum extending for about three-quarters of valve length. Brachiophores small, supported by bases which converge onto median septum at about one-third of valve length anterior to umbo ; sockets small, defined by fulcral plates.

		Length	Width
Holotype.	Ventral valve (BB.30245) .	3·7 mm.	—
Paratypes.	Ventral valve (BB.30246) .	2·5 mm.	4·55 mm.
	Ventral valve (BB.30247) .	2·1 mm.	4·8 mm.
	Dorsal valve (BB.30248) . .	2·0 mm.	—
	Dorsal valve (BB.30249) . .	2·9 mm.	—

Discussion. Whilst *Skenidioides* is a commonly occurring genus in the Portrane fauna, 235 ventral and 128 dorsal valves being recovered, the majority of the specimens are too fragmentary to contribute much to the description of the species.

The shells belong to two distinct species, *S. paucicostatus* sp. nov. and *S.* cf. *asteroidea* Reed. The former is transverse and alate, with a few coarse subangular costae and seldom any costellae, a sharp dorsal sulcus, and ventral fold whose median rib is much stronger than the remainder. The latter differs in being of sub-pentagonal outline, with a higher interarea, less angular ribs with costellae developed, and a gentle fold and sulcus on which the ribs are of even size. Data obtained for the two species is compared as follows :—

Length (l) : width (w) of ventral valve.

	S. cf. *asteroidea*	*S. paucicostatus*
n	17	16
l (var. l)	4·34 (3·602) mm.	2·83 (0·708) mm.
$\bar{w}$ (var. w)	5·56 (5·362) mm.	5·96 (2·361) mm.
r	0·9012	0·8525
a (var. a)	1·220 (0·01888)	1·826 (0·06507)

A comparison of the valve outlines from the above statistics shows *S. paucicostatus* to be significantly more transverse than *S.* cf. *asteroidea* (·05 > P > ·02). The adult *S. paucicostatus* does not attain the length of the larger *S.* cf. *asteroidea* ; but growth-lines on the latter indicate that the sub-pentagonal shape is maintained throughout growth, so that there is no chance of *S. paucicostatus* being simply the young of the other species in the same way that the auriculate young forms of *S. obtusus* develop rounded cardinal extremities in later life (Cooper 1956 : 497).

Length (l) : thickness (t) of ventral valve.

	S. cf. *asteroidea*	*S. paucicostatus*
n . . .	14	18
l (var. l) . . .	4·46 (2·424) mm.	2·98 (0·723) mm.
$\bar{t}$ (var. t) . . .	2·24 (1·028) mm.	1·43 (0·180) mm.
r	0·8584	0·8561
a (var. a) . . .	0·6512 (0·009298)	0·499 (0·004158)

A comparison of the two species reveals no significant differences in either the a or b values for valve profile.

Length of valve (l) : length of ventral interarea (ia).

The impression of greater length of the interareas in *S.* cf. *asteroidea* may in fact be due to the greater overall size of those valves when compared with *S. paucicostatus*; accordingly data were taken in order to compare the growth rates for the two samples.

	S. cf. *asteroidea*	*S. paucicostatus*
n . . .	28	34
l (var. l) . . .	4·50 (2·313) mm.	3·03 (0·670) mm.
ia (var. ia) . . .	1·79 (0·513) mm.	1·00 (0·067) mm.
r	0·8478	0·7898
a (var. a) . . .	0·4708 (0·002396)	0·316 (0·00117)

A " t " test shows *S.* cf. *asteroidea* to have a significantly longer interarea ($\cdot 02 > P > \cdot 01$). Although tests for allometric growth proved negative, it is apparent from a plot of the points on a graph (Text-fig. 2) that the specimens over 5 mm. long all tend to have relatively long interareas. These are all *S.* cf. *asteroidea* and thus may be biasing the " a " value.

Accordingly percentage values of length of interarea : length of valve (m) were calculated for the whole sample of *S. paucicostatus*, and compared with values of *S.* cf. *asteroidea* for a sample in the same size range, i.e. up to 4·9 mm. in length :

	S. cf. *asteroidea*	*S. paucicostatus*
n . . .	19	34
$\bar{m}$ (var. m) . . .	37·4% (53·7)	33·6% (29·4)

On testing, $P \approx \cdot 06$, showing that with this selected sample the relatively greater interarea length of *S.* cf. *asteroidea*, just moves out of the 5% significance level.

For the ventral interior, a bivariate analysis carried out on the length of the spondylium (s) and the valve length (v) reveals no significant difference between the two samples :—

	S. cf. *asteroidea*	*S. paucicostatus*
n . . .	16	11
$\bar{v}$ (var. v) . . .	4·34 (2·091) mm.	3·13 (0·45) mm.
$\bar{s}$ (var. s) . . .	1·53 (0·324) mm.	1·02 (0·078) mm.
r	0·8908	0·7764
a (var. a) . . .	0·3937 (0·003394)	0·4163 (0·007649)

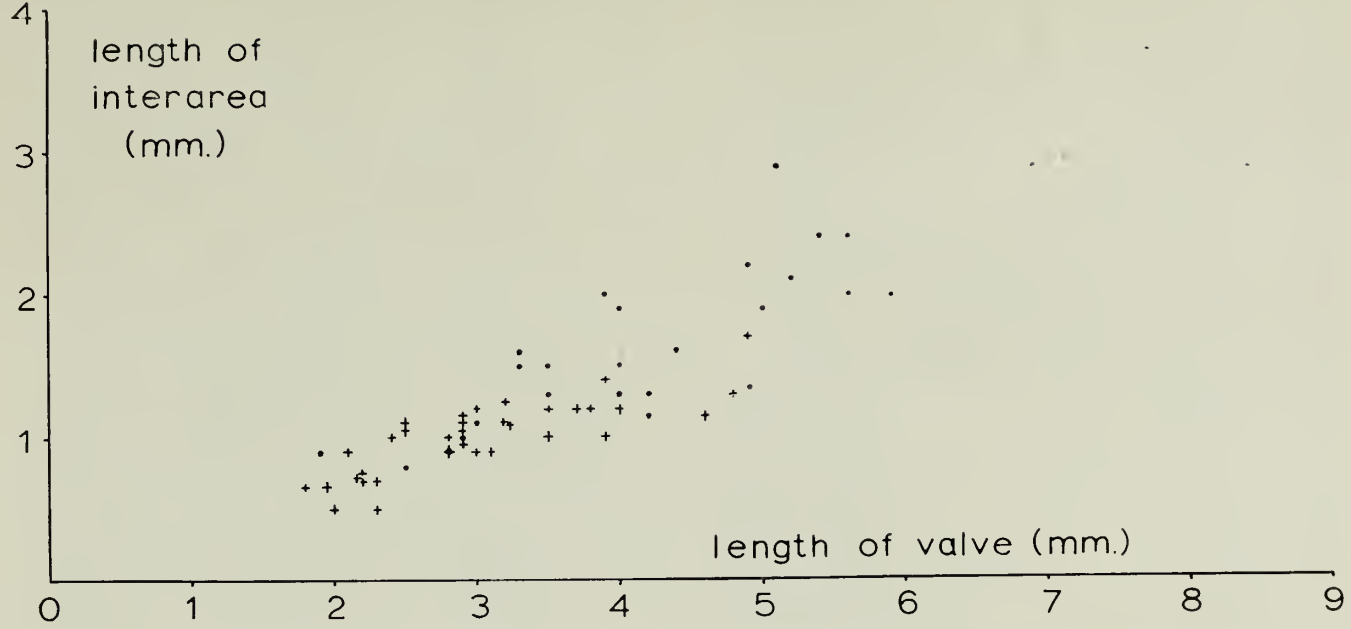

FIG. 2. Graph showing the relationship between the length of the ventral valve and the length of the ventral interarea in samples of *Skenidioides* cf. *asteroidea* (Reed) (·), and *Skenidioides paucicostatus* sp. nov., (+).

As for the ventral valve, the dorsal outline for *S. paucicostatus* is significantly wider than for *S.* cf. *asteroidea*, 10 valves of the former having a mean percentage length : width of 51·2% (var. 65·7) compared with 65·7% (var. 86·6) for 15 valves of the latter ($P < ·001$).

The length of the cardinalia : length of dorsal valve expressed as a percentage for 7 valves of *S. paucicostatus* are 27, 27, 30, 30, 31, 32, 33% ; and for 10 specimens of *S.* cf. *asteroidea* 22, 26, 26, 29, 30, 32, 32, 35, 37, 40% : these are not significantly different.

A bivariate analysis of the length of the dorsal median septum (s) : length of the dorsal valve (v) also shows no significant difference.

	S. cf. *asteroidea*	*S. paucicostatus*
n . . .	15	11
$\bar{s}$ (var. s) . . .	2·89 (0·877) mm.	2·02 (0·225) mm.
$\bar{v}$ (var. v) . . .	3·89 (1·465) mm.	2·77 (0·295) mm.
r	0·8978	0·8112
a (var. a) . . .	1·292 (0·02492)	1·145 (0·04982)

It is necessary to enlarge upon some details of the ornamentation given in the diagnosis, for this is one of the most important specific characters of the genus. The total number of ribs measured at 2 mm. from the ventral umbo for *S.* cf. *asteroidea* was 11–19 on 1, 4, 4, 4, 3, 2, 6, 1, 1 valves respectively ; and for *S. paucicostatus*, 7–13 on 5, 4, 8, 5, 2, 0, 2 valves respectively. A 2×2 test (Table 6) shows a significant difference in the two samples ($P < ·001$).

TABLE 6

	7–11 ribs	12–20 ribs
S. cf. *asteroidea*	1	25
S. paucicostatus	24	2

TABLE 6. Table for 2×2 contingency test comparing the frequencies of ribbing densities for *S.* cf. *asteroidea* and *S. paucicostatus*, counts being taken at 2 mm. from the ventral umbo. At a distance of 3 mm. from the ventral umbo 12–21 ribs were present on 1, 2, 3, 2, 1, 1, 3, 0, 1, 1 valves of *S.* cf. *asteroidea* compared with 7–10 ribs on 2, 1, 3, 3 valves of *S. paucicostatus*.

While the mean wavelength of the ventral median costa of *S. paucicostatus* is significantly larger ($P < ·001$) than its neighbouring lateral rib (0·77 mm. (var. 0·0203) and 0·48 mm. (var. 0·0051) respectively for 32 valves), the median and lateral ribs of *S.* cf. *asteroidea* show no significant difference (0·35 mm. (var. 0·0132) and 0·34 mm. (var. 0·0052) respectively for 24 valves) ; the lateral ribs of the former species are further significantly larger than those in the latter ($P < ·001$).

The median rib of *S. paucicostatus* is invariably prominent. In *S.* cf. *asteroidea* the usually even ribbing is somewhat variable. Thus a median rib more marked than its neighbours was observed in 11/44 valves ; but in six of these the exaggeration was only very slight whilst in four of the other five valves it was due to the median rib producing a fascicle of ribs.

Skenidioides paucicostatus is quite distinct from all other described stocks of the genus, especially in the alate outline, the relatively few coarse ribs, and the strongly

developed median costa of the ventral valve. A stronger median rib also characterises the ventral valve of *S. mediocostatus* Cooper 1956, but is much less developed, measurements on Cooper's figures 19, 26 on pl. 97, c, giving a wavelength at 2 mm. of 0·5 and 0·4 mm. Further, the ribs as a whole are finer and more numerous (20, 19, 20 at 2 mm. on the three dorsal valves [figs. 21, 24 and 28]) than in *S. paucicostatus*. These two differences also apply to *S. costatus*. *S. oelandicus* (Wiman) from the Swedish Leptaena Limestone resembles *S. paucicostatus* in the alate hinge-line and other features, but possesses many more ribs and lacks the pronounced median rib of the ventral valve.

The second Portrane species is placed close to *S. asteroidea* (Reed). An examination of the type material of this species from the Drummuck beds at Girvan reveals close agreement with the Portrane valves particularly in shape and outline. The ornamentation is even and of the same style, with 2a° developed before the other externals in the ventral valve. The ribbing is rather fine on the Scottish shells ; but nevertheless both the wavelength and the total number of ribs are within the limits of variation of the Portrane material. Although Reed (1917 : 921) described the Drummuck specimens as having a less carinate and more rounded ventral valve than *S. craigensis*, one of the specimens of the type material (B.72689) certainly has a sharper and more angular fold than is usual in the Portrane shells, which tend to resemble the more gently folded specimen B.72691. Thus, while it seems certain that the Portrane shells are close to the Drummuck shells, a larger sample of the latter will have to be examined in order to ascertain whether the two are absolutely conspecific. *S. asteroidea* was recorded from both the upper and lower Drummuck by Lamont (1935 : 299). In the older Whitehouse Beds the genus is represented by *S. greenhoughi*, which has a finer ornamentation than *S. asteroidea*, according to Reed (1917 : 921) consisting of " 24–30 simple rounded equal closely placed low ribs ". A small sample of this species revealed a somewhat larger range in rib density with 32, 22, and 19 ribs present on three ventral valves at 3 mm. from the umbo. Including Reed's figured specimen (1917, pl. 21, fig. 32) which has 29 ribs at 3 mm., the sample of four is significantly different (P=·004 in a Rank Sum Test) from the ten specimens of *S.* cf. *asteroidea* which show the largest number of ribs at this distance (see above p. 216).

Figures given for *S.* cf. *costatus* from the Gelli-grîn Calcareous Ashes by Williams (1963 : 376) show that it resembles *S.* cf. *asteroidea* in many characters. Comparisons of the length : width and length : height of the ventral valve, and of the length of cardinalia : length of dorsal valve reveal no significant differences. The ornamentation, too, is similar in the ventral valve development of 2a° before 1a°, 3a° and 4a°, but differs in having a median rib stronger than the rest in this valve. In this respect it resembles *S. paucicostatus* (see above).

S. billingsi from the Rockland Formation in Quebec (Schuchert & Cooper 1932 : 72) and *S. impressus* from the younger Percé Formation (Cooper & Kindle 1936 : 353) are the closest of the American species to *S.* cf. *asteroidea*, but both differ in possessing a finer ornamentation, which is well outside the range of variation of the Portrane shells.

Family **SAUKRODICTYIDAE** nov.

Diagnosis. Aberrant biconvex and sulcate orthaceids with distinctive ornamentation of costae and costellae developed within a honeycomb network. Interareas short ; delthyrium and notothyrium open. Ventral interior with teeth supported by short, strong dental lamellae. Dorsal interior with short, divergent brachiophores, with supporting plates which converge to form notothyrial platform ; cardinal process simple ; fulcral plates absent.

Genus *SAUKRODICTYA* nov.

Diagnosis. Ventri-biconvex shells of rather transverse outline ; strong median fold on ventral valve and corresponding deep sulcus on dorsal valve ; anterior commissure sulcate. Radial ornamentation of costae and costellae forming integral part of honeycomb meshwork covering surface. Ventral interarea curved, apsacline ; dorsal interarea short, anacline ; delthyrium and notothyrium open. Shell substance apparently impunctate.

Ventral interior with teeth supported by short, strong, receding dental lamellae. Muscle field imperfectly known. Dorsal interior with deep sockets, without fulcral plates and bounded medianly by short brachiophores, whose supporting plates converge medianly to form notothyrial platform ; this projects medianly into elongatedly subquadrate adductor field. Diductors inserted on notothyrial platform on either side of cardinal process, which is a low simple ridge.

Discussion. The assemblage of characters possessed by the new genus indicates it to be an aberrant orthoid. These characters are however so distinctive that the genus cannot be placed in any existing brachiopod family with confidence ; accordingly the new family Saukrodictyidae is proposed to accommodate the single genus.

Unfortunately the type, and so far the only, species of the genus is rare in the Portrane faunas, and the few specimens available are all damaged. However, they are sufficiently well preserved to establish the majority of the structural features, although there is some doubt about the structure of the cardinal process. This appears to consist of a very low simple ridge on the notothyrial floor. A small piece of siliceous material does form a prominence along this ridge but it is uncertain whether this is part of the cardinal process which has been broken, or whether it is a small piece of silica adhering to the valve in this position.

The exterior features which immediately distinguish the genus from all other stocks are firstly the ornamentation and secondly the overall shape, with the very strongly developed ventral fold and dorsal sulcus.

The ornamentation consists umbonally of costae ; with growth of the shell these diverge, and in the intercostal spaces there develops a series of tiny calcareous plates perpendicular to the surface of the shell. These are arranged to form a basic pattern of two rows of " pores " between adjacent costae, with a zig-zag series of plates

dividing the rows longitudinally. The " pores " in fact are not holes at all, but simply spaces between the plates which form the walls of the honeycomb meshwork (Pl. 7, fig. 29). Thus, although the ribs usually project to a slightly greater extent, the honeycomb itself stands out markedly from the surface of the valve. Costellae may arise by a thickening along the line of the zig-zag series of plates ; subsequently a double series of " pores " will again develop between the costella and the adjacent costa when increased growth permits.

Although in detail the ornamentation of *Saukrodictya* is quite unlike that of any other described brachiopod, several forms are known to have a rather similar ornamentation, including such genera as *Eichwaldia*, *Porambonites*, *Punctolira* and *Linoporella*.

Eichwaldia, whose taxonomic position is uncertain, has a net-like ornamentation, although it lacks the radial ornamentation of that in *Saukrodictya*. Here the resemblance ceases, *Eichwaldia* being totally different from the new genus in all features of the hinge region and valve interiors.

Whilst the syntrophoids *Porambonites* and *Punctolira* possess a net-like type of ornamentation, it gives the effect of single rows of fine pores usually arranged radially between fine radial costellae, a somewhat different arrangement from that of *Saukrodictya*. As with all syntrophoids, the fold and sulcus are on the opposite valve to *Saukrodictya*, whilst the internal structures further separate them from the Portrane genus.

Linoporella shows similarities to *Saukrodictya* in several ways. The ornamentation is, however, much closer in detail to that of species of *Porambonites* (Schuchert & Cooper 1932, pl. 18, fig. 33). The plication, although also found on the ventral valve, is extremely gentle and bears no comparison in degree of development to that of *Saukrodictya*. *Linoporella* also lacks the wide hinge-line of the new genus.

Internally the ventral valve of *Linoporella* has the dental plates continued forward to bound a somewhat elongate muscle field, anterior to which is a pronounced median ridge ; *Saukrodictya* on the other hand has short receding dental plates and no median ridge. In the dorsal valve of *Saukrodictya*, the sockets are much deeper and the brachiophores less well developed than in *Linoporella* ; this may be accounted for by the smaller size of the Portrane genus. Although *Saukrodictya* lacks the median septum and cruralium typical of the linoporellids, a certain similarity may be observed in the convergence of the brachiophore plates to form the notothyrial platform on the valve floor (instead of on a septum), and the muscle field too shows an elevated periphery as in some *Linoporella*.

The genus *Linoporella* is, of course, a punctate form. No evidence of punctation can be seen on the specimens of *Saukrodictya* but, as already indicated above (p. 168), in silicified material this is not necessarily conclusive. Should an unsilicified specimen be found in the other brachiopod faunas of the same age which are at present under investigation, and should this show the shell substance to be punctate, it will of course be necessary to transfer the family from the orthaceids to the dalmanellaceids.

TYPE SPECIES. *Saukrodictya hibernica* sp. nov.

Saukrodictya hibernica gen. et sp. nov.

(Pl. 7, figs. 21, 23, 24, 26, 28–30)

Diagnosis. Small, ventri-biconvex shells of transverse outline ; hinge-line wide, cardinal angles slightly obtuse, angular ; postero-lateral margin gently convex becoming strongly convex antero-laterally ; antero-medianly the outline is affected by the strong fold. Ventral valve with prominent rounded fold giving trilobate appearance to valve ; dorsal valve with corresponding deep rounded sulcus, both fold and sulcus arising very close to umbones. Ventral valve with strong median costa along the fold, with about four costae developed on either side ; between costae, costellae develop within honeycomb meshwork. Ventral interarea curved, apsacline, about one-fifth as long as valve ; dorsal interarea very short, anacline ; delthyrium and notothyrium open.

Ventral interior with stout teeth supported by strong receding dental plates ; muscle field poorly defined by apparent marginal thickening showing scar to be rather broad, with median adductor scar extending slightly forward of diductor scars. Dorsal interior with short brachiophores, bounding deep sockets ; cardinal process ridge weakly developed, situated on notothyrial platform formed by convergence of brachiophore supporting plates ; notothyrial platform extended anteriorly into subquadrate adductor field from which it is clearly separated by raised periphery, produced from anterior continuance of brachiophore plates. Adductor field also with raised margin.

		Length	Width
Holotype.	Damaged dorsal valve (BB.30255) . . .	3·1 mm.	—
Paratypes.	Broken ventral valve (BB.30256) . . .	4·1 mm.	—
	Broken ventral valve (BB.30257) . . .	3.9 mm.	—

Superfamily **DALMANELLACEA** Schuchert & LeVene 1929

Family **DALMANELLIDAE** Schuchert & Le Vene, 1929

Genus ***DALMANELLA*** Hall & Clarke 1892

Dalmanella portranensis sp. nov.

(Pl. 8, figs. 11, 12, 14–19, 21, 26)

1846 *Orthis testudinaria* Dalman ; M'Coy : 35.
1853 *Orthis testudinaria* Dalman ; Medlicott : 268.
1861 *Orthis testudinaria* Dalman ; Baily : 12 (*pars*).
1880 *Orthis testudinaria* Dalman ; Baily : 82 (*pars*).
1895 *Orthis testudinaria* Dalman ; Sollas : 101 (*pars*).
1897 *Orthis elegantula* Dalman? ; Reed : 537.
1897 *Orthis testudinaria* Dalman ; Reed : 537.
1963 *Dalmanella* sp., Williams & Wright : 8.

Diagnosis. Gently sulcate, ventri-biconvex shells of sub-circular outline. Ventral valves almost as long as wide, hinge-line about two-thirds of maximum

valve width ; thickness averaging about two-fifths of valve length. Lateral profile showing maximum convexity near umbo ; anterior profile with middle of valve more sharply convex than flanks, with only slight tendency to form a fold. Interarea curved, apsacline, approaching one-quarter as long as wide and one-sixth as long as valve ; delthyrium open. Dorsal valves over four-fifths as long as wide, and averaging about one-sixth as deep as long, shallowly convex in both profiles, anterior profile depressed medianly by narrow sulcus originating at umbo, becoming broad and shallow anteriorly to produce a gently and broadly sulcate anterior commissure. Interarea short, anacline, about one-eighth as long as wide ; notothyrium open. Ornamentation of costellae, typically with 3 ribs per mm. at 5 mm. anterior to dorsal beak.

Ventral interior with stout teeth, supported by strong dental lamellae which continue forward to define a muscle field averaging over two-thirds as wide as long and almost two-fifths as long as valve. Thickened adductor scar about one-third of the width of complete scar, and slightly shorter than bounding median diductor lobes. A pair of slightly divergent *vascula media* extend from anterior ends of median diductor lobes. Dorsal cardinalia extending for almost one-quarter of valve length comprising undifferentiated bilobed cardinal process with generally weak shaft on thickened notothyrial platform ; brachiophores subtending an angle of about 30° relative to plane normal to median ridge, and mean angle of divergence between posterior edges of brachiophores of about 60°, with angle of divergence of bases on valve floor slightly, but not significantly, less : socket pads, fulcral plates and crural pits variably developed. Subquadrate adductor field about two-thirds as wide as long and extending for half valve length, with anterior adductor pair larger and wider than posterior pair ; a weak median ridge divides the scar longitudinally.

		Length	Width
Holotype.	Dorsal valve (BB.30267) .	10·1 mm.	10·8 mm.
Paratypes.	Dorsal valve (BB.30268) .	9·4 mm.	c. 11 mm.
	Ventral valve (BB.30269) .	10·3 mm.	10·5 mm.
	Ventral valve (BB. 30270) .	10·1 mm.	10·0 mm.
	Dorsal valve (BB.30271) .	6·4 mm.	c. 7·5 mm.

Discussion. This species of *Dalmanella* is of common occurrence in the Portrane Limestone, and has been recorded as *D. testudinaria* by various authors since 1846. *Dalmanella testudinaria*, also an Upper Ordovician form, has recently been redescribed from a sample of topotype material from Borenshult, Sweden (Williams & Wright 1963 : 29). A comparison of the data for the Swedish shells with the data for the Portrane shells (given below), shows that on external characters the two species cannot be distinguished.

Statistical tests on the outline of both dorsal and ventral valves reveal no significant differences in either the growth ratios or the initial shapes ; nor for the thickness : length ratio of the ventral valve. A bivariate analysis of thickness : length for the dorsal valve shows the value of the correlation coefficient, r, to be too low to warrant the determination of a and b ; but although the modal percentage for

the Swedish valves (14%) is less than for the Portrane specimens (17%), it still falls within the range (11–23%) for the Portrane sample.

The density of the ornamentation measured at 5 mm. anterior to the dorsal umbo shows 2–4 ribs present on 1, 27, 12 valves respectively, a very similar distribution to that of *D. testudinaria*. The more important rib relations are given in Table 7, the data for *D. testudinaria* being taken from Williams & Wright, Table 6. Of the larger counts obtained, only the relative development of 2a⁻1⁻ to 2b⁻ is markedly different in the two forms ; but in view of the large number of specimens in which the earlier of the two ribs could not be determined, no significance can be attached to this difference.

TABLE 7

Relation	*D. testudinaria* s.s.	*D. portranensis*
1a⁻1⁻) 1b⁻	3/5 (13)	0/2 (1)
2b⁻1⁻) 2a°	4/5 (–)	– –
2c⁻) 2a°	5/6 (–)	2/2 (–)
2b⁻) 2a°	33/33 (–)	24/24 (–)
2a⁻1⁻) 2b⁻	7/8 (24)	4/12 (12)
3c⁻) 3a°	12/17 (1)	12/15 (3)
3b⁻) 3a°	38/38 (1)	18/18 (3)
4b⁻) 4b°	8/16 (13)	4/4 (–)
4a⁻1°) 4b⁻1⁻	2/3 (3)	– –
3a⁻1⁻a⁻) 2a°	28/28 (–)	16/17 (–)
3a⁻1⁻a⁻) 3a°	– –	11/15 (2)
3b⁻1⁻) 3c⁻	– –	0/10 (6)

TABLE 7. Table comparing the frequencies of twelve rib associations in the dorsal valves of *Dalmanella testudinaria* (Dalman) from Borenshult, Sweden, with *Dalmanella portranensis* sp. nov. The number in parentheses indicates the frequency of valves in which the earlier rib of the association could not be determined.

In the dorsal valves, the tendency is for the cardinal process shaft and also the median ridge to be very much weaker in *D. portranensis* than in *D. testudinaria*, but this is not invariable. The statistical comparisons used for the brachiophores by Williams & Wright, i.e. the angle subtended by the brachiophores relative to a plane normal to the median ridge, the angle subtended between the posterior edges and also between the bases of the brachiophores, show no significant differences between these two species. For the first of these comparisons, a sample of 19 Portrane valves have a mean angle of 31·9° (var. 58·3) ; 37 valves show the mean divergence of the posterior edges to be 60·8° (var. 36·9), and the bases 58·5° (var. 43·4), the bases being slightly convergent but not significantly so.

The brachiophores of the Portrane valves do differ significantly from those of the Swedish shells in extending further forward relative to the length of the valves.

Length of cardinalia : valve length.

D. testudinaria, 5 valves—16, 19, 19, 20, 20%.

D. portranensis, 10 valves—18, 19, 21, 22, 22, 22, 23, 23, 25, 28%.

A Rank Sum Test carried out on these data indicates the two species to be significantly different (P=·020).

The adductor scars have the same disposition in both species, with the maximum width located in the larger anterior pair ; although data for the Swedish shells is scant for both length : width of the scar, and for the length of the scar relative to the valve length, it does indicate the two species to be practically identical in both aspects.

Apart from the length of the brachiophores, the most striking difference between the two species is found in the ventral muscle field. The stronger dental lamellae of the Portrane species are almost subparallel in contrast to the weaker, widely divergent lamellae of the Swedish species ; the muscle field of the latter is accordingly broad and cordate in contrast to the narrower, subtriangular to slightly bilobate scar of the new species.

Rank Sum Tests on the dimensions of the muscle scar show the narrower scar of the Portrane species to be significantly different (P=·030) from that of the Borenshult form, although there is no significant difference in the lengths of the muscle scar relative to the valve length.

Width : length of ventral muscle field.

D. testudinaria, 2 valves—80, 94%.

D. portranensis, 10 valves—67, 68, 68, 72, 73, 73, 74, 77, 79, 82%

Length of muscle field : length of ventral valve.

D. testudinaria, 3 valves—33, 36, 39%.

D. portranensis, 10 valves—35, 35, 35, 38, 38, 39, 40, 40, 40, 46%.

A ventral index (Williams & Wright 1963 : 18) of ·45 was obtained for a solitary Portrane valve ; the lateral diductor lobe is situated on the lower part of the dental lamella and the adjustor scar in a well marked groove between the dorsal edge of the lateral diductor lobe and the tooth itself. Two valves show the median diductor lobes to extend beyond the adductor scar by 14 and 15% of their lengths ; and 4 valves possess an adductor scar whose width is 25, 25, 37, and 41% of that of the complete scar.

The species *Orthis wysogorskii* differs from *D. testudinaria* (and also *D. portranensis*) according to Wiman (1907 : 10), in having a ventral interarea which is almost in the plane of commissure and which is hardly curved (it may also be noted that it is very short, being less than 10% of the valve length in Wiman's pl. 1, fig. 23*a*), and also in the narrow angle of divergence of the brachiophores.

The closest of the Girvan shells of Upper Ordovician age to the new species are the Whitehouse form designated by Reed (1917 : 856) as *Dalmanella testudinaria* var. and the Drummuck *Dalmanella elegantula* var. *drummuckensis* (Reed 1917 : 850). Differences from the Portrane shells can be found in the posterior dorsal adductor scars being larger than the anterior pair in the former species, and in the short, broad ventral muscle scar (Reed 1917 : pl. 9, fig. 12) in the latter, which in spite of its poor definition anteriorly is closer to one-quarter of the valve length, rather than over one-third as in the Portrane species.

It becomes very evident from the work of Williams & Wright on the dalmanellids that details of the cardinalia and ventral muscle field in particular are fundamental in determining the *genus* to which dalmanellids belong ; and until an exhaustive study of the Whitehouse and Drummuck dalmanellids has been completed, comparisons with the Girvan shells will remain unsatisfactory.

The following statistical data were obtained for *Dalmanella portranensis:—*

Ventral valves.

Length (*l*) *: width* (*w*). n=52 ; $\bar{l}$ (var. l)=7·63 mm. (4·092) ; $\bar{w}$ (var. w)=8·01 mm. (4·270) ; r=0·9795 ; a (var. a)=1·021 (0·0008472).

Length (*l*) *: thickness* (*t*). n=53 ; $\bar{l}$ (var. l)=7·95 mm. (4·185) ; $\bar{t}$ (var. t)=3·09 mm. (0·521) ; r=0·9285 ; a (var. a)=0·3528 (0·000336).

Length (*l*) *: width* (*w*) *of interarea.* n=26 ; $\bar{l}$ (var. l)=1·21 mm. (0·09849) ; $\bar{w}$ (var. w)=5·20 mm. (1·724) ; r=0·9042 ; a (var. a)=4·183 (0·1329).

Length of interarea (*l*) *: valve length* (*v*). n=33 ; $\bar{l}$ (var. l)=1·20 mm. (0·07406) ; $\bar{v}$ (var. v)=7·77 mm. (3·584) ; r=0·8397 ; a (var. a)=6·956 (0·4603).

Width of hinge-line (*x*) *: width of valve* (*y*). n=24 ; $\bar{x}$ (var. x)=4·93 mm. (1·441) ; $\bar{y}$ (var. y)=7·58 mm. (3·922) ; r=0·9326 ; a (var. a)=1·65 (0·01613).

Dorsal valves.

Length (*l*) *: width* (*w*). n=32 ; $\bar{l}$ (var. l)=8·17 mm. (2·686) ; $\bar{w}$ (var. w)=9·40 mm. (3·166) ; r=0·9493 ; a (var. a)=1·086 (0·003886).

Length (*l*) *: thickness* (*t*). n=19 ; $\bar{l}$ (var. l)=8·51 mm. (1·994) ; $\bar{t}$ (var. t)=1·44 mm. (0·08638) ; r=0·3581.

Length : width of interarea, expressed as a percentage, 9 valves—10, 12, 12, 12, 12, 12, 14, 14, 15%.

Length : width of muscle field, 9 valves—57, 65, 65, 66, 67, 70, 70, 71, 72%.

Length of muscle field : length of valve, 6 valves—49, 51, 52, 53, 55, 57%.

Genus ***BANCROFTINA*** Sinclair 1946

Bancroftina sp.

(Pl. 9, figs. 1, 2, 4, 5)

Description. Transverse dalmanellids with flatly convex dorsal valves, possessing a strong, rounded sulcus rising close to the umbo and becoming deep anteriorly ; sulcus bounded laterally by swollen flanks which flatten postero-laterally. Dorsal interarea short, slightly curved, strongly anacline, about three-quarters as wide as the valve ; notothyrium filled by myophore. Ornamentation costellate, with 3 ribs per mm. at 5 mm. antero-median to the umbo.

Cardinal process with prominent, trilobed? myophore and weak shaft ; sockets bounded by brachiophores about one-sixth as long as the valve, with bases almost sub-parallel to hinge-line ; posterior edges of brachiophores diverge at 78°, bases at 97° in the figured specimen. Fulcral plates and crural pits absent, ancillary struts not well defined. Adductor field quadripartite, divided longitudinally by a strong rounded median ridge. Ventral valve unknown.

Discussion. The above description is based principally on one fairly well preserved dorsal valve (BB.30272), 8·8 mm. long and 13·4 mm. wide, supplemented by a few other fragmentary dorsal valves. The cardinalia, comprising widely divergent brachiophores with the bases sub-parallel to the hinge-line without fulcral plates, together with a cardinal process which appears to be trilobed, suggest inclusion in *Bancroftina* rather than in any other dalmanellid genus. When compared with specimens of *B. typa* and *B. robusta* there are differences in detail ; the cardinal process of the Portrane specimens has a larger myophore which projects from the notothyrium, with a weaker shaft on a shallower notothyrial platform, and with the tops of the brachiophores rather more widely divergent than usual for the Caradocian forms. Externally the sulcus of the Portrane valves is certainly deeper than in the other species.

With the material available, the variation, particularly of the cardinalia, cannot be accurately assessed ; however, none of the differences observed in the Portrane material seem to be of more than specific importance, and the shells are accordingly placed provisionally in *Bancroftina*.

Family **SCHIZOPHORIIDAE** Schuchert 1929

Subfamily **ISORTHINAE** Schuchert & Cooper 1931

Genus ***ISORTHIS*** Kozlowski 1929

Isorthis ? ***bailyi*** sp. nov.

(Pl. 8, figs. 20, 22–25, 27–31)

Diagnosis. Slightly asymmetrical ventri-biconvex shells of transversely oval outline, thickness of conjoined valves about three-fifths of ventral length ; anterior commissure rectimarginate. Ventral valves over four-fifths as long as wide, with maximum width at about mid-valve, hinge-line over half valve width ; interarea short, curved, apsacline, less than one-tenth of valve length ; delthyrium open. Lateral and anterior profiles evenly convex. Dorsal valve slightly shallower, evenly convex in lateral profile, with convex anterior profile very slightly indented medianly by short narrow sulcus, which is usually lost in valves over 4 mm. long ; interarea very short, anacline, notothyrium partially closed by cardinal process. Radial ornamentation of hollow angular costae and costellae, density 2 to 3 per mm. at 5 mm. growth stage ; branching dominantly internal.

Ventral interior with stout teeth, supported by dental plates which continue anteriorly as ridges to define muscle field, details of which are uncertain. Dorsal cardinalia composed of cardinal process with bilobed myophore and short, stout shaft, passing rapidly into shallow notothyrial platform ; brachiophore bases slightly divergent relative to tops in figured specimen, but not significantly so ; sockets defined by well developed fulcral plates. Subquadrate adductor field divided longitudinally by low median ridge, anterior adductor pair slightly larger than posterior pair.

		Maximum Length	Width
Holotype.	Complete shell (BB.30273) .	8·5 mm.	9·7 mm.
Paratypes.	Complete shell, ventral valve slightly deformed (BB.30274)	c.6·5 mm.	7·9 mm.
	Dorsal valve (BB.30275) .	6·4 mm.	7·5 mm.

Discussion. This species is quite distinct from the associated *Dalmanella* in having a ventri-biconvex profile, an oval outline, a dorsal sulcus in the early growth stages which rapidly fades, a generally rectimarginate anterior commissure and a very short ventral interarea.

In profile and in the development of hollow costae especially, the Portrane species resembles Cooper's genus *Mendacella* (1930*a* : 377) which is known from Upper Ordovician as well as Lower Silurian strata. However, the disposition of the brachiophores of this stock is quite different, the bases being widely divergent relative to the tops (Williams & Wright, 1963 : 28) ; neither is the characteristic ventral sulcus developed in the Portrane valves, although this could be a reflection of the smaller size of the Irish shells.

The genus *Isorthis* has not, as yet, been recorded from the Ordovician or early Silurian rocks, and the Portrane species is placed here principally because of its greater morphological similarity to *Isorthis* than to any other described genus, the specimens not providing sufficient data for a categoric generic placing. The relatively coarse nature of the ornamentation is more characteristic of the associated *Dalmanella* than of known species of *Isorthis*, whose ornamentation is typically rather fine ; the attitude of the brachiophores, too, would appear to be intermediate between those of *Dalmanella* and of *Isorthis*, but with the large time interval involved the differences from *Isorthis* s.s. may not be as important as they first appear.

Using the Portrane sample at present available, the shells are placed provisionally with *Isorthis*. It may be that the species occurs elsewhere in rocks of similar age under the name of "*Dalmanella testudinaria*", a form from which it is certainly both specifically and generically distinct.

Family **DICOELOSIIDAE** Cloud 1948

Genus ***DICOELOSIA*** King 1850

Dicoelosia lata sp. nov.

(Pl. 9, figs. 3, 6, 9, 12, 14–19)

Diagnosis. Transverse *Dicoelosia* with only moderate invagination of anterior margin producing characteristic bilobed appearance. Ventral valve about two-thirds as long as wide, with mid-line length four-fifths of maximum valve length, and two lobes diverging at average angle of 70°. Valve approaching half as deep as long, strongly and evenly convex in lateral profile ; anterior profile also strongly convex, grooved medianly by steep-sided narrow sulcus which originates at umbo and is less than 1 mm. wide at the 2 mm. growth stage. Interarea curved, apsacline, about one-quarter as long as wide and one-quarter as long as valve ; delthyrium

open. Hinge-line wide, about two-thirds of valve width ; cardinal extremities obtuse and flattened to produce small ears. Dorsal valve averaging three-fifths as long as wide, with uneven surface producing profile varying from gently convex to gently concave ; posterolateral areas flat, separated from median sulcus by strongly pronounced lobes, which themselves vary from convex to concave in lateral profile. Sulcus deep, originating at umbo, twice as wide as ventral sulcus and more gently rounded. Interarea very short, flat, anacline ; notothyrium open. Ornamentation of costae and costellae ; ventral valve with median costa in sulcus, which contains up to 8 ribs at front margin in largest specimens, with up to 13 in corresponding dorsal sulcus. Rib density of 4–6 ribs per mm. measured at 2 mm. distance anterolaterally along crest of lobe from ventral umbo. Dorsal ribbing pattern showing replacement of internal ribs by external ribs outwards from sector 2 to sector 4.

Ventral interior with teeth supported by convergent dental lamellae ; muscle field about as wide as long, and about one-third of valve length. Diductor scars extending slightly beyond but not enclosing median adductor scar. A pair of *vascula media* develop from anterior ends of diductor scars. Dorsal interior with long cardinal process ridge (shaft) on unthickened notothyrial floor, occasionally with small swelling (myophore) preserved at posterior end. Brachiophores blade-like, with bases slightly divergent on to valve floor to bound sockets ; cardinalia about half as long as wide, and about one-third as long as valve. Adductor scars and pallial markings not known.

		Maximum Length	Width
Holotype.	Complete shell (BB.30276)	4·5 mm.	5·6 mm.
Paratypes.	Ventral valve (BB.30277)	4·6 mm.	7·0 mm.
	Ventral valve (BB.30278)	3·2 mm.	3·7 mm.
	Ventral valve (BB.30279)	c. 3·6 mm.	5·3 mm.
	Ventral valve (BB.30280)	c. 5 mm.	6·2 mm.
	Dorsal valve (BB.30281)	3·6 mm.	5·5 mm.
	Dorsal valve (BB.30282)	3·0 mm.	4·8 mm.

Discussion. The genus *Dicoelosia* has a long stratigraphical range, being recorded from rocks of Upper Ordovician to Middle Devonian age. The Portrane form is characterised particularly by its transverse shape, wide hinge-line, the very moderate invagination of the anterior margin and the high angle of divergence of the two lobes. Detailed statistical data for these and other characters of the species are given below. For the bivariate analysis of maximum valve length to valve width of the ventral valves, a sample of 41 Portrane shells just failed to show allometric effects at the 5% level ($\cdot 1 > P > \cdot 05$), whilst for a sample of 36 dorsal valves allometry was established ($\cdot 05 > P > \cdot 02$). In his recent redescription of *Dicoelosia varica* (Conrad), Amsden (1958 : 53) includes data for 17 shells from the Haragan Formation of Oklahoma, which on testing show allometric effects for the outline of the ventral valve. Accordingly the corresponding allometric data for the Portrane shells are here included, and a comparison by "t" test of the length : width of the ventral valves shows the Irish form to be significantly more transverse ($\cdot 01 > P > \cdot 001$)

than *D. varica*. This Devonian species is also quite different from *D. lata* in the convex dorsal valves and the relatively narrow hinge-line of the former, although the two are similar in the small degree of invagination of the anterior commissure. *D. oklahomensis*, from the Upper Silurian Henryhouse Formation, differs from *D. varica* in commonly having a more pronounced bilobation ; as evidence of this Amsden (1958 : 54) cites one specimen which has a median length : maximum length ratio of only 50%. Further data is not available for *D. oklahomensis*, but Amsden's earlier figures (1951, pl. 15) tend to confirm this deeper invagination, the median length being about 75 and 78% of the maximum length in his figures 5 and 7 respectively, which only just fall within the range for *D. varica* given in Table 3 (1958 : 53). Thus *D. oklahomensis* differs from the Portrane shells also on this character, as well as such features as valve outline and relative width of the hinge-line which it shares with *D. varica*.

The type species, *D. biloba* Linnaeus, is a Wenlock form whose exact range is still rather uncertain due to the rather indiscriminate use of this specific name in the past. The locality from which Linnaeus' type was obtained is not known (Davidson 1869 : 207) ; accordingly the attributes of the type species were obtained from Kozlowski's description of Polish shells placed in this species (1929 : 60). A comparison between this species and *D. lata* shows similarities in the valve convexities and in the anterior invagination, and differences in the less transverse outline, shorter hinge-line, and finer, less pronounced ribbing of the Wenlock form.

Amongst the described Ordovician stocks is *D. indenta* (Cooper) from the Whitehead Formation of Percé, Quebec. As stated by Whittard & Barker (1950 : 578), Cooper's figured specimen (1930, pl. 1, fig. 4) appears to be poorly preserved. They suggested that it may turn out to be identical with their Upper Llandovery form *D. alticavata*.

A sample of 46 Portrane ventral valves shows a mean divergence of the lobes (measured as the angle subtended by the ventral umbo and the antero-lateral extremities of the two lobes) of 68° (var. 64°) ; in Cooper's figure of *D. indenta* the lobes diverge at 53°, which is slightly less than the lowest recorded for the Portrane valves. In *D. alticavata*, the lobes diverge at " about 35–40° " according to Whittard & Barker (1950 : 577) ; this agrees with their fig. 16 on pl. 8 (36°), although it is apparently somewhat higher (c. 52°) in fig. 18. Marked contrast between *D. lata* and these other two forms is further seen in their very deep anterior invagination and less transverse outline.

Reed (1917 : 848) recorded a variety of *D. biloba* from the Whitehouse Beds at Girvan, which is distinctive in possessing a marked central rib in the ventral sulcus ; on shell shape, however, Reed's figure (1917, pl. 9, fig. 4) falls within the range of variation of the Portrane valves on the length : width ratio, angle of divergence of the lobes, and the depth of the anterior invagination, although this last is rather deep for the Portrane sample. Reed's dorsal valve (fig. 6) has a length : width ratio of 90%, which is well outside the range of the Portrane sample. The Llandovery ventral valves figured by Reed (1917, pl. 9, figs. 1, 2) as *D. biloba* are, as noted by Whittard & Barker, quite distinct from the type species and they may be at once

distinguished from the Portrane shells by the less divergent lobes and the less transverse outline.

Dicoelosia cor, described by Wiman (1907 : 9) from the Leptaena Limestone of Sweden, shows a resemblance to the Portrane species in its general shape and small anterior invagination, as does the Whitehouse form. Strong costae develop sporadically, and a median one is present on the figured ventral valve (Wiman 1907, pl. 1, fig. 12) as in the Scottish shells. The Swedish species differs from *D. lata* particularly in the dorsal interior. Here the brachiophores are extremely long, protruding ventrally, in contrast to the low, plate-like brachiophores of *D. lata*. The bases of the brachiophores are also less divergent, and show a continuation anteriorly in the form of a low ridge to form a clear boundary to the muscle field, which is unknown in the Irish shells. Externally, the ventral valve of *D. cor* appears to lack a sulcus ; and the invagination of the anterior commissure appears to be even less pronounced than in *D. lata*, although most of Wiman's figured specimens are fragmentary, so that statistical data cannot be obtained for this character. The high interarea of the ventral valve (Wiman's fig. 13) is greater than for any of the Portrane sample, but in the text (p. 9) Wiman states that this character is very variable, most only being half the height of this figured specimen. The width of the interarea : valve width varies from 82% for his fig. 13*a* down to 52% for fig. 14, the range for the Portrane shells (see below) being very much less (57–75%).

A detailed study of the variation of the features of the Scottish and Swedish shells is necessary before the relations between these three can be satisfactorily ascertained.

The following statistical data was obtained for the Portrane sample :—

(a) *Ventral valves.*

Maximum length (*l*) *: maximum width* (*w*). n=41 ; $\bar{l}$ (var. l)=3·09 mm. (0·4647) ; $\bar{w}$ (var. w)=4·49 mm. (1·3315) ; r=0·8604 ; a (var. a)=1·692 (0·01907) ; $\overline{\log_e l}$ (var. $\log_e$ l)=1·1045 (0·0475) ; $\overline{\log_e w}$ (var. $\log_e$ w)=1·4699 (0·0640) ; r_e=0·8616 ; α (var. α)=1·161 (0·008973).

Mid-line length (*m*) *: maximum length* (*l*). n=35 ; $\bar{m}$ (var. m)=2·53 mm. (0·3691) ; $\bar{l}$ (var. l)=3·17 mm. (0·5285) ; r=0·9679 ; a (var. a)=1·196 (0·002743).

Maximum length (*l*) *: thickness* (*t*). n=19 ; $\bar{l}$ (var. l)=3·31 mm. (0·3827) ; $\bar{t}$ (var. t)=1·50 mm. (0·09945) ; r=0·8628 ; a (var. a)=0·5097 (0·003906).

Length of ventral valve (*l*) *; thickness of complete shell* (*t*). n=10 ; $\bar{l}$ (var. l) =3·04 mm. (0·4845) ; $\bar{t}$ (var. t)=1·77 mm. (0·2312) ; r=0·8202 ; a (var. a) =0·6908 (0·01953).

Length (*l*) *: width* (*w*) *of interarea.* n=12 ; $\bar{l}$ (var. l)=0·87 mm. (0·0334) ; $\bar{w}$ (var. w)=3·32 mm. (0·90) ; r=0·8780 ; a (var. a)=5·190 (0·6172).

Length of interarea (*x*) : *maximum valve length* (*y*). n=15 ; $\bar{x}$ (var. x)= 0·88 mm. (0·2821) ; $\bar{y}$ (var. y)=3·39 mm. (0·6045) ; r=0·8806 ; a (var. a)= 4·629 (0·3701).

Maximum width of interarea (*x*) : *maximum valve width* (*y*). n=20 ; $\bar{x}$ (var. x)=3·22 mm. (0·8547) ; $\bar{y}$ (var. y)=4·89 mm. (1·692) ; r=0·9618 ; a (var. a)=1·407 (0·08247).

Length (*l*) : *width* (*w*) *of ventral muscle scar.* n=11 ; $\bar{l}$ (var. l)=1·28 mm. (0·1012) ; $\bar{w}$ (var. w)=1·17 mm. (0·0632) ; r=0·9128 ; a (var. a)=0·7903 (0·01158).

Length of ventral muscle scar : valve length. 3 specimens only :— muscle scar 34, 34, and 36% of the valve length.

Origin of ventral sulcus (M mm. from umbo). n=13; $\bar{M}$ (var. M)= 0·34 mm (0·0175).

Width of ventral sulcus at 2 mm. growth stage (m). n=23 ; $\bar{m}$ (var. m)= 0·94 mm. (0·03727).

(b) *Dorsal valve.*

Maximum length (*l*) : *maximum width* (*w*). n=36 ; $\bar{l}$ (var. l)=2·85 mm. (0·2408) ; $\bar{w}$ (var. w)=4·71 mm. (1·132) ; r=0·7863 ; $\overline{\log_e l}$ (var. $\log_e$ l)= 1·0328 (0·0290) ; $\overline{\log_e w}$ (var. $\log_e$ w)= 1·5248 (0·0498) ; r_e=0·7947 ; α (var. α)=1·31 (0·01928).

Mid-line length (*m*) : *maximum length* (*l*). n=28 ; $\bar{m}$ (var. m)= 2·47 mm. (0·1700) ; $\bar{l}$ (var. l)=2·99 mm. (0·2467) ; r=0·9605 ; a (var. a)=1·204 (0·008031).

Length (*l*) : *width* (*w*) *of cardinalia.* n=16 ; $\bar{l}$ (var. l)=0·92 mm. (0·06468) ; $\bar{w}$ (var. w)=1·81 mm. (0·1166) ; r=0·8368 ; $\overline{\log_e l}$ (var. $\log_e$ l)=$\bar{l}$·8797 (0·0738) ; $\overline{\log_e w}$ (var. $\log_e$ w)=0·5759 (0·0348) ; r_e=0·8426 ; α (var. α)= 0·6866 (0·01009).

Length of cardinalia (*c*) : *maximum valve length* (v). n=11 ; $\bar{c}$ (var. c)= 0·90 mm. (0·0708) ; $\bar{v}$ (var. v)=2·82 mm. (0·296) ; r=0·8256 ; $\overline{\log_e c}$ (var. $\log_e$ c)=$\bar{l}$·8526 (0·0840) ; $\overline{\log_e v}$ (var. $\log_e$ v)=1·0185 (0·0365) ; r_e=0·8288 ; α (var. α)=0·6592 (0·01538).

Width of dorsal sulcus at 2 mm. growth stage (*M*). n=18 ; $\bar{M}$ (var. M)= 2·05 mm. (0·112).

(c) *Ornamentation.*

Rib density, measured at 2 mm. distance along the crest of the ventral lobe antero-laterally to the umbo, of 4–6 ribs per mm. on 14, 20, and 2 valves respectively. Data on costellae development, and ribs present in the sulci given in Tables 8–10 below.

TABLE 8

Rib relation	Frequency
$2a^{-}$) $2a^{\circ}$	5/5
$3a^{-}$) $2a^{\circ}$	10/10
$3a^{-}$) $3a^{\circ}$	26/28 (3)
$3a^{-}$) $4a^{-}$	10/10
$3a^{-}1^{-}$) $2a^{\circ}$	4/4
$4a^{-}$) $4a^{\circ}$	0/10 (1)

TABLE 8. Frequencies of relative costella development on dorsal valves of *Dicoelosia lata* sp. nov., figures in parentheses indicating that the ribs arose simultaneously.

TABLE 9

Maximum shell length (mm.)	*Number of ribs in the ventral sulcus*						
	2	3	4	5	6	7	8
0–0·9	–	–	–	–	–	–	–
1·0–1·9	–	–	–	–	–	–	–
2·0–2·9	–	1	2	3	–	–	–
3·0–3·9	1	–	1	–	2	1	–
4·0–4·9	–	–	–	2	1	–	1

TABLE 9. Table showing the number of ribs present in the ventral sulcus at the anterior commissure for given lengths of valves.

TABLE 10

Maximum shell length (mm.)	*Number of ribs in dorsal sulcus*		
	11	12	13
2·0–2·9	3	1	–
3·0–3·9	1	1	1

TABLE 10. Table showing the number of ribs present in the dorsal sulcus at the anterior commissure for given lengths of valves.

Family **HARKNESSELLIDAE** Bancroft 1928

Genus ***REUSCHELLA*** Bancroft 1928

Reuschella sp.

(Pl. 9, figs. 7, 8, 10, 11, 13)

1861 *Orthis vespertilio* J. de C. Sowerby ; Baily : 11.
1880 *Orthis vespertilio* J. de C. Sowerby ; Baily : 82.
1895 *Orthis vespertilio* J. de C. Sowerby ; Sollas : 101.

DESCRIPTION. Biconvex shells of transversely subrectangular outline, attaining up to 40 mm. in width ; strongly developed ventral fold and dorsal sulcus arising at the umbones. Cardinal angles usually obtusely rounded, with maximum valve width slightly anterior to the wide hinge-line. Ventral valve unevenly convex, about one-third as deep as long, with a sharply angular median fold standing well above the more gently convex flanks. Interarea curved, apsacline, about one-eighth as long as wide ; delthyrium open. Dorsal valve moderately convex in lateral

profile ; anterior profile deeply incised by the strong sulcus ; interarea very short, less than half as long as that of the ventral valve ; notothyrium open. Radial ornament coarsely fascicostellate, with about 30 angular costae and costellae developed at the 5 mm. growth stage on the dorsal valve. At the 5 mm. growth stage two ventral valves show a density of 3 ribs per 2 mm. immediately external to sector 1.

Ventral interior with teeth supported by strong dental lamellae which are continued anteriorly to form a raised periphery to the muscle field. Muscle field suboval, with narrow, strongly impressed median adductor scars bounded laterally, but not enclosed, by the diductor scars ; a pair of *vascula media* extend anteriorly from the thickened inner margins of the submedian diductor lobes. Dorsal interior with a swollen cardinal process situated on a thickened notothyrial platform ; myophore crenulated, of trilobed appearance with the median lobe extending more posteriorly than the lateral lobes, all lobes fusing into a short shaft anteriorly. Sockets long, widely divergent, defined by strong fulcral plates ; brachiophores short, subtriangular blades with grooved inner surfaces and dorsal edges convergent on to the sides of the notothyrial platform posteriorly, to form relatively deep crural pits.

Figured Specimens	Length	Width
Broken dorsal valve (BB.30283) . .	20·5 mm.	c. 36 mm.
Asymmetrical dorsal valve (BB.30284) .	13·4 mm.	—
Dorsal fragment (BB.30285) . . .	13.6 mm.	—
Broken ventral valve (BB.30286) . .	—	—
Ventral fragment (BB.30287) . . .	—	—

Discussion. Of the 15 fragments of this form available for study, preservation was such that the ribbing relations (Bancroft, 1928a : 191) were obtained for just one small dorsal valve, and even then only the ribs of sectors 1–3 could be established with certainty. Only the following four relationships used by Bancroft (1945 : 238) and Williams (1963 : 415) regarding the relative insertion of the costellae were obtained for this specimen : — $2a^{-}1^{-}$) $2a^{\circ}$, $2b^{-}$) $2a^{\circ}$, $3a^{\circ}$) $3a^{-}1^{-}$, $3a^{\circ}$) $3b^{-}$. This indicates the relatively late insertion of $2a^{\circ}$, and early insertion of $3a^{\circ}$, typical relationships for the genus (Bancroft 1945, table 9).

A count of 29 ribs developed at the 5 mm. growth stage on a dorsal valve was supplemented by counts of 14, 15 and 15 taken on three half valves, confirming the development of about 30 ribs by this stage. The width : length of the ventral muscle scar has a ratio of two-thirds for one specimen ; from the evidence of broken specimens, however, this ratio would seem to be rather variable. The length : width for the cardinalia for two specimens is 38 and 62% ; but again the sample is insufficient for any statistical comparison to be made with other forms.

Williams (1963 : 414), in discussing the two groups of Anglo-Welsh *Reuschella* of Bancroft (1945 : 239), concludes that only ribbing can be effectively used to separate the *R. bilobata* group from the *R. horderleyensis* group. The convex nature of the Portrane ventral valves, with the sharp median fold separated from the convex

flanks simply by a change in slope, without lateral folds, would seem to rule out close affinity with the *R. bilobata* group. Further the transverse shape and strong ventral fold show that it is distinct from Whittington's species *R. oblonga* (1938 : 252), but with the material at present available for the Portrane shells, comparison with other species is rather unsatisfactory. Most other described species are earlier forms of Caradocian age, although it seems likely from Twenhofel's figures (1928, pl. 16, figs. 21, 22) that *Dalmanella ruida* from the Ellis Bay formation of Anticosti Island belongs to this genus, as well as the forms from the Ashgillian of Keisley and Kildare, which have been recorded as *Orthis vespertilio* (Reed, 1897 : 69 ; Reynolds & Gardiner 1896 : 593) and are still masquerading under that name.

It is interesting to note that the crural pits of the later Portrane forms are still relatively deep in large shells. This would indicate that Bancroft's idea of a gradual filling up of the crural pits during evolution, which was supported by Havlíček (1950 : 82), is not invariably valid.

Family **LINOPORELLIDAE** Schuchert & Cooper 1931

Genus ***LATICRURA*** Cooper 1956

Laticrura erecta sp. nov.

(Pl. 10, figs. 17, 18 ; Pl. 11, figs. 16, 18–21)

Diagnosis. Subcircular ventri-biconvex shells, hinge-line about two-thirds of maximum valve width ; anterior commissure gently sulcate. Ventral valve about four-fifths as long as wide and two-fifths as deep as long ; anterior profile strongly and evenly convex with only slight indication of a fold ; lateral profile evenly convex with high, curved, apsacline interarea almost one-third as long as wide and one-quarter as long as valve ; delthyrium narrow, open. Dorsal valve about nine-tenths as long as wide and one-quarter as deep as long, with maximum convexity at umbo in lateral profile ; anterior profile depressed medianly by shallow sulcus. Interarea curved, anacline, less than one-tenth of valve length, notothyrium open. Ornamentation of fine hollow costae and costellae, typically with 4 ribs per mm. medianly at both 5 and 7·5 mm. growth stages.

Ventral interior with teeth supported by subparallel dental lamellae, whose anterior continuance defines an elongatedly rectangular muscle field about half as wide as long and two-fifths as long as valve. Apical plate usually well-developed ; adductor scar somewhat broader than flanking median diductor lobes, which may extend slightly farther forward ; lateral diductor lobes situated on dental lamellae. Dorsal interior with weak, linear cardinal process on notothyrial floor which thickens anteriorly, and is bounded laterally by almost vertical brachiophore plates ; brachiophores broad, " S "-shaped in section, and up to two-fifths as long as valve ; ventral edges diverging at about 60°, inside edges at approaching 40°. Sockets defined by fulcral plates, distance between being about one-third of valve width. Sharp, narrow median ridge extending in front of notothyrial platform for about

two-thirds of valve length, which may be over 1 mm. in height. Adductor scars poorly defined, about one-half as wide as long, and about two-thirds as long as valve.

		Length	Width
Holotype.	Dorsal valve (BB.30288). .	11·5 mm.	12·9 mm.
Paratypes.	Broken dorsal valve (BB.30289)	9·9 mm.	—
	Dorsal valve (BB.30290). .	10·6 mm.	c. 12 mm.
	Ventral fragment (BB.30291) and broken ventral valve (BB.30292) . . .	—	—

Discussion. This genus, first described by Cooper (1956) from the Caradocian rocks of the Appalachians, is also known to occur in rocks of the same age at Girvan. Although a total of five species have previously been attributed to the genus (*L. pionodema* Cooper, *L. latibrachiata* Cooper, *L. heteropleura* Cooper, *L. magna* Cooper and *L. inconstans* (Reed)), it is possible that the first and last pairs may prove to be conspecific (Williams 1962 : 145–146). Further, *L. heteropleura* is separated from the other American species essentially on the " great development of swollen and hollow costellae on the exterior " (Cooper 1956 : 981) ; but this seems to be simply a matter of degree, as a swollen rib also occurs at intervals in *L. latibrachiata* (Cooper 1956 : pl. 144, fig. 13 ; pl. 145, fig. 14) and in the Portrane species. These swollen ribs correspond in position to a rather deeper than usual marginal vascular groove on the inside of the shell.

Although the Portrane shells are similar to these other species in their general appearance, they show slight but significant differences in certain features. The new species is characterized by the more erect brachiophore supporting plates ; a shallowly convex dorsal valve with a gentle sulcus and a marked subcircular outline ; and a typical rib density of 4 ribs per mm.

The length : thickness ratio in 3 Portrane dorsal valves is 24, 26 and 26%. Williams (1962 : 144) records the dorsal valve of *L. pionodema* as being nearly one-third as deep as long. However, although the Portrane valves are generally shallower, comparison with the original data of Williams (22, 24, 31, 32, 33, 33, 38, 39%) shows that the difference is not statistically significant at the 5% level.

A comparison of the length : width percentage for 4 Portrane dorsal valves (79, 90, 93, 95%) with Williams' data for the Scottish sample of *L. pionodema* (76, 77, 77, 78, 82, 83, 83, 87, 89%), shows the former to be significantly less transverse than the latter ($P = \cdot 025$).

The two species also differ in the density of the ribbing. In the Portrane dorsal valves, counts were taken medianly at 5 and 7·5 mm. from the umbo, 3–5 ribs per mm. being present on 1, 7, 2 valves and 1, 5, 0 valves respectively. Williams' figures (p. 145) for the Scottish shells, of 4–7 ribs per mm. on 1, 5, 4, 3 valves respectively show that these valves have significantly finer ornament than the Portrane valves ($P < \cdot 001$ in a 2×2 contingency test with the measurements taken at the 7·5 mm. growth stage, see Table 11).

TABLE II

	2–4 costellae per mm.	5–7 costellae per mm.
L. pionodema . . .	1	12
L. erecta	8	2

TABLE II. Table for a 2×2 contingency test comparing the frequencies of ribbing density for a sample of *Laticrura pionodema* from Girvan (data after Williams, 1962), and of *Laticrura erecta* from Portrane.

As observed by Williams (1962 : 145), there is no important difference between the ribbing densities of *L. pionodema* and *L. latibrachiata*, and his figures for the latter (5 and 6 costellae per mm. on 4 and 2 specimens respectively) again show the ribbing to be significantly finer than in the Portrane sample. In the outline of the dorsal valve, too, *L. latibrachiata* is very much closer to *L. pionodema* ; Williams' raw data for the length : width of 6 specimens of *L. latibrachiata* are 71, 75, 78, 83, 83, 86%, these figures being significantly less than those for the Portrane sample (P=·033).

A resemblance to *L. latibrachiata* is seen in the presence of an apical plate rather than a callist in the ventral valves of *L. erecta* ; but the importance of this difference is questionable (Williams, p. 145). In the broad, shallow nature of the dorsal sulcus, the Portrane valves show greater similarity to *L. pionodema*, whilst that of *L. latibrachiata* is apparently narrow ; but sulcus development seems to be very variable within *Laticrura* populations, and accordingly must be used with discretion as a specific character.

Williams' raw data for the length : width of 4 specimens of *L. inconstans* (63, 64, 68, 70%) show this form also to be significantly more transverse than *L. erecta* (P=·014). Unlike the Portrane shells, *L. inconstans* has a fascicostellate ornamentation ; as regards the rib density, the only data available show that it is 3 ribs per mm., so that the significance of this apparently coarser ribbing cannot be ascertained statistically. *L. magna*, which may be conspecific with *L. inconstans*, also differs from the Portrane shell in its transverse shape and fascicostellate ribbing, although in rib density, " about 4 to the millimetre at the anterior margin of the holotype ", it evidently resembles the Portrane species.

L. heteropleura, too, has a more transverse outline than *L. erecta*, the holotype and figured paratype (see Cooper 1956 : 981) having dorsal length : width ratios of 75, 74% respectively. As indicated above, swollen ribs are present in both species, although this development is not so pronounced in the Irish Form.

Other biometrical attributes obtained for the new species include an assessment of the angle of divergence of the ventral edges, and also the inside edges, of the brachiophores, a sample of 12 valves having a mean (with variance) of 61° (43°) and 38° (5°) respectively. For the ratio of the length of the dorsal interarea : valve length, 7 valves show a mean of 8·99% (var. 0·37). Data for a bivariate analysis of length of median septum (s) : length of dorsal valve (l) for 9 valves is:—$\bar{s}$ (var. s)= 6·8 mm. (1·03) ; $\bar{l}$ (var. l)=9·5 mm. (1·79) ; r=0·8264 ; a (var. a)=1·318 (0·07872).

The mean length : width of the ventral interarea for 7 valves is 29·4% (var. 7·0) ; 3 valves show its length relative to valve length to be 23, 27, 28%. The width : length of the muscle field in 4 valves is 44, 51, 52, 63% ; a single valve shows the length of the scar : valve length to be 39%.

Superfamily **CLITAMBONITACEA** Winchell & Schuchert 1895

Family **CLITAMBONITIDAE** Winchell & Schuchert 1895

Genus ***VELLAMO*** Öpik 1930

Vellamo sulculata sp. nov.

(Pl. 10, figs. 1, 2, 4, 5, 8, 9, 11, 12, 14)

Diagnosis. Plano-convex to strongly ventri-biconvex shells, transverse, with maximum width usually along hinge-line giving an alate appearance. Ventral valve of variable pyramidal shape, usually .asymmetrical with umbonal region twisted. Interarea catacline to procline, rarely apsacline, with flat, concave, convex or irregularly terraced profile, approaching half as long as wide. Delthyrium about one-third as wide as hinge-line, closed by convex deltidium with large, tear-shaped foramen whose length averages almost two-fifths of interarea length. Narrow sulcus present posteriorly, becoming ill-defined by the 5 mm. growth stage, thereafter shallow, flattened or lost, except for median embayment in anterior margin. Dorsal valve about three-fifths as long as wide, flat to gently convex in lateral profile ; concave umbonally, posterolaterally and in median sulcus which separates gently convex flanks to produce a medianly indented anterior profile. Interarea very short, anacline ; notothyrium closed by low, gently arched chilidium. Ornamentation of even costae and costellae, totalling about 30 and 40 at the 5 mm. and 10 mm. ventral growth stages respectively. Fine concentric growth lines occasionally visible.

Ventral interior with teeth supported by deep, gently curved spondylium simplex with narrow flattened median zone developed in 27 out of 30 specimens ; in a single valve this zone is divided longitudinally, each part being the seat of attachment of an adductor muscle. Septum of spondylium extending for over half valve length, with rarely developed subparallel groove on either side corresponding to position of *vascula media*. Dorsal valves with notothyrial cavity divided by cardinal process ; posterior surface of notothyrial platform with two muscle scars on either side of cardinal process, inner pair marking position of attachment of diductor muscles, outer pair accessory diductor, or possibly dorsal adjustor, muscles. Socket ridges widely divergent, about one-fifth as long as wide. Quadripartite adductor field about half as long as wide and slightly less than half as long as valve, anterior pair longer than posterior. Adductor field divided longitudinally by rounded median ridge, which forks anteriorly to bound anterior adductor scars ; anterior scar subdivided into larger median scar and smaller lateral scar by oblique ridge which rises to prominent node on anterolateral edge of scar.

		Commissural Length	Width
Holotype.	Ventral valve (BB.30292) .	c. 14 mm.	20·7 mm.
Paratypes.	Damaged ventral valve (BB.30293) . . .	c. 12 mm.	c. 15 mm.
	Ventral valve (BB.30294) .	8·5 mm.	14·4 mm.
	Broken dorsal valve (BB.30295)	—	26·4 mm.
	Asymmetrical dorsal valve (BB.30296) . . .	c. 11·5 mm.	c. 18 mm.
	Damaged dorsal valve (BB.30297) . . .	c. 11 mm.	c. 17·5 mm.
	Dorsal fragment (BB.30298) .	—	—

Discussion. Like the majority of species of the genus, *V. sulculata* is asymmetrical to a greater or lesser degree. Many Portrane shells also possess a superimposed tectonic deformation which is often difficult to distinguish from the natural asymmetry of the species. Generally, however, the following features indicate tectonic deformation. Laterally compressed shells are usually elongate, with the ribs very close together and showing narrowly pinched instead of rounded crests ; valves compressed longitudinally are broad, and tend to have a convex profile ; whilst forms squashed obliquely often show ribs which are pinched on one side of the valve and rounded on the other.

Davidson (1868 : 269) commented on the wide variation in shell shape of the specimens which now belong to the genus *Vellamo*, and the lack of adequate consideration of this factor has resulted in the erection of a wealth of species, many of which appear to be simply population variants. Until samples of the thirty or more species can be obtained, and the variation of the different attributes assessed with a statistical control, the affinities of the Portrane form (and of any other sample) have to be evaluated on the evidence of one or two specimens or figures and an accompanying description. Whilst this approach may be satisfactory with the more conservative shells, *Vellamo* shows such large variation that the procedure is somewhat inadequate.

Only two species of the genus have previously been described from the British Isles. *Clitambonites shallochensis* (Davidson) emend. Reed, which was placed in synonomy with *Vellamo pyramidalis* (Pahlen) by Öpik (1930 : 213), differs from *V. sulculata* in the presence of a very deep sulcus in the ventral valve. " *Clitambonites adscendens* " was described by Davidson (1868 : 278) from the Berwyn Hills, figured by Reed (1917) from Girvan and listed by others, e.g. Groom & Lake (1908), Lamont (1935). As stated by Öpik (1930 : 213), the British specimens belong to the genus *Vellamo*, and as *C. adscendens* Pander is the type species of *Clitambonites*, the *C. adscendens* of Davidson must be a separate species. These specimens differ from *V. sulculata* in having a much shorter ventral interarea " about six times as high as long ", a less transverse outline and no indication of a ventral sulcus. Davidson's later figures (1883, pl. 16, figs. 16–18) again show the rounded outline, and a dorsal interior with the posterior adductor scars longer than the anterior scars. Figure 17, however, shows a higher interarea, and has a narrow groove in the posterior

part of the ventral valve, as seen in *V. sulculata* ; but this groove is continued along the deltidium in Davidson's figure, suggesting that the shell is deformed. Reed (1917 : 916) added little to the description, his figures (pl. 21, figs. 12–18) again showing the more rounded outline of these valves compared with the Portrane specimens.

Öpik (1934) listed 20 species and 3 subspecies of *Vellamo*, one of the species (*symmetrica*) being erected on a single valve and another (*aenigma*) on only two valves. The closest species to the Portrane form are *V. wesenbergensis*, *V. silurica*, *V. oandoensis*, *V. emarginata* and *V. pyramidalis*.

Although the dorsal muscle scars of *V. wesenbergensis* are rather poorly preserved in Öpik's figures (1934, pl. 10), the lengths of the muscle scar to the shell lengths are, as near as can be judged, 35, 34 and 38%, showing a significant difference (P=·008) when compared with the data for *V. sulculata* (given below) in a Rank Sum Test. The ventral valve lacks a sulcus, although one is shown in *V.* cf. *emarginata* figured by Schuchert & Cooper (1932, pl. 7, figs. 16, 29, 30, 32) which Öpik (1934 : 110) placed with *V. wesenbergensis*. However, this specimen does not show the posterior deepening of the sulcus as in *V. sulculata*, and differs further in having an apsacline interarea and a dorsal valve which broadens anteriorly. The Estonian form occurs in the Rakvere Stage, whose base marks the base of the Upper Ordovician (Harjuan Series) in Estonia (Rõõmusoks 1960 : 58).

V. silurica occurs at the top of the Harjuan Series in the Porkuni Stage (F11). Until recently, this stage has been regarded by many authors (e.g. Jaanusson 1944) as being of Silurian age, which accounts for Öpik's specific name. *V. silurica* resembles *V. sulculata* in its rather transverse outline, procline interarea, style of spondylium, but shows no sign of a ventral sulcus (1934, pl. 12, fig. 12). *V. oandoensis* (D111 Stage) differs in having the dorsal anterior and posterior scars of about equal length, and in having a slight ventral fold (Öpik, pl. 12, fig. 11*b*). Figure 12, however, appears to show a narrow groove on the posterior part of the valve.

Of the earlier forms, *V. emarginata*, whilst possessing a sulcus on both valves, has a comparatively elongate outline for the dorsal valve, and shows a deep median groove in the spondylium. *V. pyramidalis*, which is also supposedly characterized by a sulcus in both valves, appears to lack this in one of Öpik's figures (1930, pl. 19, fig. 226).

Amongst the American species, the Richmondian *V. diversa* (Shaler) from Anticosti is distinguished from *V. sulculata* in its consistently apsacline interarea and in the socket ridges, which diverge at 90°–100°, in contrast to *V. sulculata* where they are almost parallel to the hinge-line. *V. multistriata* (Foerste 1912 : 131) is quite distinct from the Portrane form in the fine nature of its ornamentation.

V. altissima (Winchell & Schuchert) is differentiated from their species *Clitambonites diversa* (*non* Shaler) solely on the " exceeding elevation of the cardinal area of the ventral valve " (1895 : 381). The single specimen figured by them (pl. 30, fig. 19) shows the length : width ratio for the interarea to be 73% ; whilst this is 10% higher than any from Portrane the significance cannot be established statistically

on the solitary specimen. The width of the delthyrium : width of hinge-line (42%) is the same (within limits of error) as the highest found in *V. sulculata* : this feature was used by Raymond (1921 : 28) to distinguish his species *V. reudemanni* from *V. altissima*.

V. trentonensis (Raymond) is the closest of the American forms to *V. sulculata*, although Raymond's definition (1921 : 27) is not particularly diagnostic of the species. Raymond cited *Clitambonites diversa* Winchell & Schuchert (1895, pl. 30, figs. 11–17) as belonging to his species together with the specimens figured by Hall & Clarke (1892, pl. 15A, figs. 1–4, 7, 8). Figures 7 and 8 of Hall & Clarke are in fact of the same specimen that Winchell & Schuchert figured for their variety *altissima* in pl. 30, figs. 18, 19, so that Raymond included the specimen with *V. trentonensis* when figured by Hall & Clarke, but not when figured by Winchell & Schuchert, at the same time giving a specific name to Winchell & Schuchert's variety on the following page.

V. trentonensis differs from *V. sulculata* in having a spondylium with a clearly marked flat median area extending anteriorly ; in having the anterior adductor scars shorter than the posterior scars in the dorsal valve ; and in the possession of a rather angular chilidium. The figures of Schuchert & Cooper (1932, pl. 7, fig. 18) and Cooper (1944, pl. 3, fig. 33) apparently contradict the last two points, and underline the necessity for statistical comparisons between samples of the various species in order that the most important factor of variation be put in correct perspective. The exteriors figured by Hall & Clarke and Winchell & Schuchert, show the presence of a sulcus in both valves, and although it is seemingly absent from the umbonal region of the ventral valve, the other features of this apparently very variable species indicate that it is close to *V. sulculata*.

The following statistical data were obtained for the Portrane sample which comprises over 150 valves, although the majority of these are fragmentary or else tectonically deformed. The ventral valves possess a strongly pyramidal profile, and accordingly measurements have been taken for both the surface length and the commissural length (see Text-fig. 1). The low values of the correlation coefficient in the data for shell shape reflect the large shape variation of this species.

(a) *Ventral valve.*

Orientation of the umbo. In a sample of 40 valves, the umbones are directed posteriorly, anteriorly and vertically in 21, 15 and 4 valves respectively.

Width of delthyrium (*x*) *: width of hinge-line* (*y*). n=12 ; $\bar{x}$ (var. x)=5·76 mm. (0·82) ; $\bar{y}$ (var. y)=17·28 mm. (12·42) ; r=0·89 ; a (var. a)=3·89 (0·31).

Length (*l*) *: width* (*w*) *of interarea.* n=12 ; $\bar{l}$ (var. l)=8·46 mm. (3·57) ; $\bar{w}$ (var. w)=18·44 mm. (8·47) ; r=0·37.

Commissural length (*c*) *: valve width* (*w*). n=8 ; $\bar{c}$ (var. c)=10·35 mm. (2·84) ; $\bar{w}$ (var. w)=17·33 mm. (16·15) ; r=0·46.

Surface length (*s*) *: valve width* (*w*). n=8 ; $\bar{s}$ (var. s)=13·16 mm. (10·31) ; $\bar{w}$ (var. w)=17·33 mm. (16·15) ; r=0·42.

Length of foramen (f) : length of interarea (l). n=13 ; $\bar{f}$ (var. f)=3·32 mm. (0·64) ; $\bar{l}$ (var. l)=8·95 mm. (4·23) ; r=0·41.

Distance anterior to umbo where sulcus melts into flanks (l) : width of sulcus at this point (w). n=12 ; $\bar{l}$ (var. l)=4·36 mm. (2·43) ; $\bar{w}$ (var. w)=1·51 mm. (0·34) ; r=0·7223 ; a (var. a)=0·375 (0·0067).

Distance from anterior end of median septum to anterior margin (x) : surface length of valve (y). n=6 ; $\bar{x}$ (var. x)=5·63 mm. (3·63) ; $\bar{y}$ (var. y)=13·48 mm. (12·48) ; $\overline{\log_e x}$ (var. $\log_e$ x)=1·67 (0·109) ; $\overline{\log_e y}$ (var. $\log_e$ y)=2·57 (0·067) ; r=0·9614 ; r_e=0·9589 ; a (var. a)=1·85 (0·065).

(b) *Dorsal valve.*

Length (l) : width (w). n=7 ; $\bar{l}$ (var. l)=11·07 mm. (5·12) ; $\bar{w}$ (var. w)=18·1 mm. (17·7) ; r=0·599.

Length of adductor field : length of valve, 7 specimens—42, 43, 44, 48, 48, 49, 51%.

Length of anterior scar : length of adductor field, 7 specimens—57, 66, 67, 69, 70, 73, 76%.

Length : width of muscle field, 4 specimens—49, 50, 51, 52%.

Distance from angle of " fork " of median ridge to anterior margin (x) : valve length (y). n=9 ; $\bar{x}$ (var. x)=4·77 mm. (3·09) ; $\bar{y}$ (var. y)=9·14 mm. (6·77) ; $\overline{\log_e x}$ (var. $\log_e$ x)=1·499 (0·127) ; $\overline{\log_e y}$ (var. $\log_e$ y)=2·174 (0·078) ; r=0·9426 ; r_e=0·9320 ; α (var. α)=0·78 (0·0115).

Length (l) : width (w) of socket ridges. n=12 ; $\bar{l}$ (var. l)=1·72 mm. (0·225) ; $\bar{w}$ (var. w)=8·86 mm. (4·623) ; r=0·772 ; a (var. a)=4·53 (0·827).

In this last analysis, " length " is measured from the base of the cardinal process on the notothyrial platform to the most anterior extension of the socket ridges ; whilst " width " is taken as the distance between the points on either side where the socket ridges show a decided " kink " (in some specimens they terminate here, in others they continue towards the lateral margins as low ridges).

(c) *Surface ornamentation.*

Total numbers of ribs at the 5 mm. growth stage on 6 ventral valves are 24, 28, 29, 29, 30, 32 and on 4 dorsal valves 30, 33, 34, 37. At the 10 mm. growth stage, 2 ventral valves possess 38, 39 ribs and 3 dorsal valves 42, 46, 47 ribs.

Rib density is given in Table 12 below.

TABLE 12

Ribs/median 2 mm.	3	4	5	6	3	4	5
at 5 mm. . .	–	3	15	4	–	7	8
at 7 mm. . .	–	16	3	–	1	7	6
at 10 mm. .	6	8	1	–	6	5	–
		(a)				(b)	

TABLE 12. Rib frequency for (a) ventral and (b) dorsal valves of *Vellamo sulculata* sp. nov., at various growth stages.

Vellamo sp.

(Pl. 10, figs. 6, 7)

One dorsal valve (BB.30299) of this genus is quite distinct from *Vellamo sulculata* sp. nov. in possessing a differentiated radial ornamentation. The strong median costa is separated by a weaker costa (rib 2) from a strong lateral costa (rib 3) on either side ; both 2 and 3 produce an internal costella ($2a^-$ and $3a^-$), so that at the margin the three strong ribs are separated from each other by three finer ribs. External to the strong lateral costae, this differentiation is lost.

Although the valve is partially caked with silica on its inner surface, and the median parts of the chilidium and cardinal process broken, the cardinalia quite clearly indicate that the specimen belongs to the genus *Vellamo*, in spite of the unusual external ornamentation. The flat valve is 3·0 mm. long and has a maximum width along the alate hinge-line of over 6 mm., the cardinal extremity being broken on one side. Nineteen ribs are present at the margin.

Family **KULLERVOIDAE** Öpik 1934

Genus ***KULLERVO*** Öpik 1934

Kullervo complectens (Wiman) ***albida*** (Reed)

(Pl. 10, figs. 3, 10, 13, 15, 16, 19, 20)

1917. *Clitambonites complectens* (Wiman), var. *albida* Reed: 916, pl.21, figs. 19,20.

Description. Plano-convex to strongly ventri-biconvex shells with a pyramidal ventral valve of B-shaped outline with maximum width about half the commissural valve length (see Text-fig. 1) located along hinge-line; posterolateral regions concave, bounded by convex flanks on either side of a well-defined sulcus which is about one-fifth as wide as the valve. Ventral surface flat to gently convex in lateral profile, commissural length about three-quarters of surface length. Ventral interarea usually somewhat curved, apsacline umbonally becoming flat and catacline, about half as long as wide, and almost as long as the commissural valve length. Delthyrium about one-third as wide as the hinge-line, closed by convex deltidium with a pedicle foramen usually large, occupying up to half the length of the delthyrium and possessing an asymmetrical calcareous lip which may project up to 3 mm. away from the surface of the interarea. Dorsal valve with minute but prominent convex umbo, variably alate with maximum valve width at hinge-line, length to width ratios of 42, 44 and 58% being recorded for 3 valves ; valve profile flat, with gently convex areas developing antero-laterally, separated by a shallow sulcus medianly and bounded by flatter or concave areas posterolaterally. Elevated concentric ridges prominent over whole shell surface, usually stronger than the radial ornament although the ribs bounding the sulcus show a greater prominence in 2/10 ventral valves. Frequency of concentric ridges per 2 mm. of valve length, measured medianly anterior to 3 mm. growth stage, is 4, 5, 5, 5, 6 in five ventral valves. Concentric ornamentation invariably dominant and often the sole marking on

posterolateral areas of both ventral and dorsal valves ; elsewhere well developed costae and costellae produce a reticulate pattern with the concentric ridges. Ventral sulcus delimited on either side by costa which is clearly much stronger than any other radial rib in 10/12 specimens ; the other two specimens have a neighbouring one or two external costae of similar strength. Number of radial ribs in sulcus (and on shell) varies according to strength of development, with 5–7 on clearly reticulate forms, whilst only 1–3 may be discernible where radial ornament is less prominent, when concentric ridges tend to develop eminences in positions where ribs are developed in the more reticulate forms. Counts of strong ribs (and where reticulation is well developed, only the stronger ribs of the pattern) on left flank external to rib bounding sulcus show 1–4 ribs on 1, 5, 4, 2 specimens respectively. Total ribs occurring on flank external to sulcus bounding rib at 3 mm. growth stage are 7–10 on 4, 4, 0, 1 valves respectively ; these numbers are however very much dependent on the clear definition of the ribs. Dorsal ornamentation similar, with shallow sulcus bounded by strong rib on either side and a further 2 or 3 strong ribs external to these.

Ventral interior with simple teeth, spondylium supported by median septum receding ventral to spondylium but advancing near valve floor to pass into median ridge, the latter being simply an internal representation of the sulcus. Hemisyrinx present, with hemisyringeal walls variably developed ; subspondylial septa clearly seen in one specimen, which has a complementary ridge on the valve floor on one side. Traces of vascular markings observed marginally. Dorsal cardinalia dominated by ponderous, widely divergent socket ridges approaching one-third as long as wide, with only a narrow space between their thick posterior ends ; 3 valves show no cardinal process in this space ; 2 valves have a simple process, and another shows a small process developing medianly and ventrally from the chilidium, whilst a further specimen possesses a piece of siliceous material between the socket ridges which may or may not be a cardinal process. Antero-medianly socket ridges separated by thick notothyrial platform, passing anteriorly into a usually well defined median ridge. Chilidium, or traces of it, usually visible ; traces of adductor scars seen on only one side of a single specimen, located between median ridge and socket ridge with apices directed postero-medianly, typical for genus.

Figured Specimens	Length*	Width
Ventral valve (BB.30330) . . .	5·9 mm.	c. 11 mm.
Ventral valve (BB.30331) . . .	4·5 mm.	5·2 mm.
Dorsal valve (BB.30332) . . .	2·9 mm.	c. 6 mm.

* Overall length in plane of commissure, including deltidium.

Discussion. The ventral sulcus of this species is quite clearly developed, although inclined to be shallow, and may broaden gradually to produce a narrow sulcus, or alternatively very rapidly to produce a wide sulcus (see Reed 1917, pl. 21, figs. 19, 20). A sample of 5 valves shows the mean width of the sulcus relative to valve width to be 21·3% (var. 8·5). The mean ratio of the commissural length : valve width for 5 ventral valves is 49·4% (var. 31·7) ; for 7 valves the ratio of

commissural length : surface length is 72·8% (var. 118·9). Data obtained for the ventral interarea shows the mean length to be 47·9% of the width (var. 47·2) in a sample of 5 valves ; a mean length relative to commissural length of 98·6% (var. 299·8) for 6 valves ; and the mean width of delthyrium : width of interarea of 34·2% (var. 22·3) in a sample of 5 valves.

The extremely large variation in the shape of the ventral valve of this species becomes apparent from the figures given above, so that it may be difficult to separate different samples on this feature alone. A statistical comparison has been made between the species here described and the three specimens of *K. lacunata* figured by Öpik (1934, pl. 36), using the length : width percentage of the socket ridges of the dorsal valve as a statistic. The figures for the Portrane sample of 7 valves are 25, 25, 27, 29, 32, 32, 33%, and for *K. lacunata* 34, 39, 39%. A Rank Sum Test indicates that the two species are significantly different in this attribute (P=·008).

The spondylium of *Kullervo* is an interesting one ; Öpik (1934 : 28) described it as being a degenerate spondylium triplex, the form of spondylium found in *Estlandia*, etc. This is based on the presence of a pair of ridges situated under either side of the spondylium which lie along the undersurface and extend for the length of the spondylium, in a somewhat similar manner to the hemisyringeal walls on the upper surface, but further away from the median line than those structures.

Whittington & Williams (1955 : 413) disagreed with Öpik as they found " indications of the rudimentary 'spondylial septa' " in one specimen only ; and from their absence in other specimens, particularly in immature forms, they suggested that the " septa " were the products of mantle deposition in late stages of growth, and were probably not homologous with the lateral septa of the true spondylium triplex.

In brachiopods with an undoubted spondylium triplex such as *Antigonambonites* and *Estlandia* the middle septum is short, particularly in the umbonal region, so that the spondylium is close to the valve floor (Öpik 1934, text-fig. 3).

Progonambonites shows lateral septa at the apex of the spondylium which pass forward as ridges under the spondylium, with counterparts on the valve floor (Öpik 1934 : 27, text-fig. 4). At this stage the median septum is higher and stronger and deposition of the lateral septa as continuous partitions ceases. The condition in *Kullervo* may be likened to a late stage in this degeneration of the lateral plates, resulting from the elevation of the spondylium well above the valve floor.

In the Portrane material many specimens are caked with silica, especially internally, so that only 5 specimens show a clear spondylium. One adult shows very well developed subspondylial septa ; in the other specimens, especially the two younger ones, the ridges are not so obvious, due principally to the fact that in early stages they lie very close to the edge of the spondylium, only becoming clear as the spondylium deepens. The best specimen also shows a well defined ridge on the floor of the valve on one side which would correspond to the ventral base of the degenerate septum of Öpik's interpretation.

Thus whilst Whittington & Williams are certainly correct in calling this structure a spondylium simplex, it does seem likely that it evolved from a spondylium triplex,

as suggested by Öpik, by a strengthening of the median septum and weakening, with subsequent atrophy, of the lateral septa.

When Öpik erected the genus *Kullervo*, he used surface sculpture as a means of dividing the species into four groups (p. 162). In his first group he placed *K. panderi* Öpik and *K. intacta* Öpik, these being characterized by a dominant radial ornamentation, with a fine concentric ornamentation, and a reticulate pattern only on the ears (p. 165, fig. 37). The second group with *K. lacunata* Öpik and *K. aluverensis* Öpik shows strong radial ribs in the middle sector but on the ears the concentric ornamentation is dominant. In the third group *K. complectens* (Wiman) shows concentric ornamentation as strong as the radial over the whole of the valve ; whilst *K. complectens albida* he placed in a fourth group with the concentric ornamentation dominant over the whole of the valve.

The strong concentric ornamentation of the Portrane species separates it from the first two groups. A species of *Kullervo*, *K. pyramidata*, was recorded by Cooper & Kindle (1936 : 353) from the Upper Ordovician Whitehead formation of Quebec. This is rather similar to the Portrane form (and *K. complectens*) especially in occasionally showing a distorted lip to the foramen. It differs from the Portrane form in having barely any sulcus in the ventral valve, radial ribs of even size and which seem to be much more prominent than the concentric ornamentation in the figures (Cooper & Kindle 1936, pl. 51, figs. 1, 2) although from the text the " heavy concentric lines (are) of almost as great strength as the costellae ".

One other Irish species of *Kullervo*, *K. hibernica*, has been recorded by Harper (1952 : 100) from the Caradocian rocks of Grangegeeth. This is generally much closer to *K. panderi*, and differs from the Portrane specimens especially in its much finer and more even radial ornamentation.

Cooper (1956) has erected four species from the Lower Middle Ordovician of Virginia and Alabama. *K. ornata* differs from the Portrane species especially in the outline of the dorsal valve, being less transverse, without the alate hinge region, and lacking the concave posterolateral areas ; and in possessing a very wide delthyrium (50% of the length of the hinge-line in his pl. 80, fig. 2), in the small apical deltidium and better developed walls to the hemisyrinx. Cooper distinguishes this species from *K. parva* of the same horizon by the convex dorsal valve and subordinate concentric ornamentation of the latter. The ornamentation of *K. ornata* is much closer to the Portrane species than Cooper's other species in having the posterolateral areas covered dominantly by concentric ornamentation.

K. sulcata, known only from the ventral valve, resembles the Portrane form in having a well-defined sulcus bounded by a strong costella, but here, as in *K. parva*, the radial ornamentation is the dominant element in the middle sector of the valve. Cooper's other species, *K. punctata* differs considerably in shape and ornamentation from the Portrane form.

Reed (1917) erected his subspecies of *K. complectens* on two ventral valves from the Whitehouse Beds, Shalloch Mill, Girvan, stating it to differ from *K. complectens* s.s. only in having the radial ornamentation scarcely developed at all, so that the reticulate ornamentation is not so apparent (Reed, pl. 21, figs. 19, 20). Wiman's

form shows strong reticulation produced from radial and concentric ornamentation of equal strength (1907 : pl. 1, fig. 2b). In the Portrane sample four out of twelve ventral valves agree with Reed's types. Of the others one specimen shows a strong reticulation in the umbonal region only, whilst three other specimens showing this are small forms (i.e. may be compared to umbonal regions of large ones) of less than 4 mm. surface length. Two specimens show reticulation moderately developed, and only two with it well developed over most of the shell. So from this variation in the Portrane sample it would seem likely that a larger sample of the Girvan material may show this too.

The Portrane specimens are accordingly here placed in Reed's subspecies, differing from *K. complectens* s.s. in having the sulcus bounded by a rib stronger than the other ribs ; and in the concentric ornamentation being generally dominant, rather than equal to the radial ribbing.

Superfamily **TRIPLESIACEA** Schuchert 1913
Family **TRIPLESIIDAE** Schuchert 1913
Genus ***TRIPLESIA*** Hall 1859
Triplesia cf. ***insularis*** (Eichwald)
(Pl. 11, figs. 1, 2, 6, 7, 9, 10, 15)

1846 *Orthis galea* M'Coy : 30, pl. 3, fig. 12.
1853 *Orthis galea* M'Coy ; Medlicott : 268.
1861 *Orthis insularis* Eichwald ; Baily : 11.
1869 *Orthis insularis* Eichwald ; Davidson : 274, pl. 37, fig. 9.
1880 *Orthis insularis* Eichwald ; Baily : 82.
1895 *Orthis insularis* Eichwald ; Sollas : 102.
1897 *Triplesia insularis* (Eichwald) Reed : 537.
1963 *Triplesia* sp., Wright, pl. 109, figs. 13, 16–19.

Description. Large, dorsi-biconvex shells attaining over 25 mm. in width, lacking ornament except for occasional faint concentric growth lines. Ventral valve only moderately convex, transverse, with maximum width slightly posterior to mid-valve (valve length measured along line of lateral commissure). Sulcus, originating at about the 4 mm. growth stage, initially a curved depression ; later this flattens medianly and becomes more pronounced with the development of a long, evenly rounded and dorsally projecting tongue. Interarea curved, apsacline, about one-sixth as long as wide and two-thirds as wide as the valve ; delthyrium closed by flat pseudodeltidium, invariably with median fold ; beak perforated by pedicle foramen. Dorsal valve strongly globose, wider than long, with a low flat-topped or gently convex fold, slightly raised above the strongly convex flanks in anterior profile ; lateral profile convex, strongly so umbonally.

Tendency for umbonal thickening in the ventral interior, with slight development of pedicle passage, and pedicle tube in some valves ; teeth supported by weak dental lamellae, which diverge to limit the muscle field posterolaterally. Diductor scars large, flabellate, almost enclosing the cordate adductor field. Dorsal interior

with slender, forked cardinal process, whose width is only about one-quarter of the distance between the distal ends of the " brachiophores "; fork fused proximally into a single unit, hood invariably present ; valve thickened umbonally.

Figured Specimens	Maximum Length	Width
Ventral valve (BB.30333) . . .	22·5 mm.	c. 25 mm.
Damaged dorsal valve (BB.30334) . .	c. 21 mm.	c. 23 mm.
Dorsal fragments (BB.30335–36) . .	—	—

Discussion. The etched specimens of this genus are poorly preserved, no dorsal valves and only 4 ventral valves being relatively complete. This is due in part to the normally very thin nature of the shells away from the umbonal regions, resulting in imperfectly silicified shells being easily damaged by the acid. A large number of the fragments consist simply of the dorsal hinge-line and cardinalia, the features of which have been recently discussed (Wright 1963 : 748). These are very distinctive when compared with those of the associated *Oxoplecia* (p. 248). The following statistical data were obtained for a sample of 14 specimens of the *Triplesia* in a bivariate analysis of cardinal process width (x) : distance between the tips of the brachiophores (y):—$\bar{x}$ (var. x)=1·11 mm. (0·10) ; $\bar{y}$ (var. y)=4·86 mm. (1·14) ; r=0·796 ; a (var. a)=3·3 (0·334).

The genus *Triplesia* is practically devoid of surface ornamentation, and as the internal structures are generally considered to be very conservative (e.g. the cardinalia) or else inadequately known for most species (e.g. pallial sinuses), specific differentiation is based principally on shell shape and the styles of folding. The species which show the greatest morphological resemblance to the Portrane specimens include *T. anticostiensis* Twenhofel 1914, *T. glabra* Williams 1951, *T. woodlandensis* Reed 1917, all of Llandovery age ; and *T. uniplicata* Cooper & Kindle 1936, *T. asteroidea* Reed 1935, and *T. insularis* (Eichwald 1842), all of Upper Ordovician age.

Holtedahl (1916 : 87), in comparing the Oslo Llandoverian *Triplesia* (*T. anticostiensis*) with the types of *T. insularis* from the Russian Lyckholm, pointed out that while there is much variation in form of the Norwegian shells, they differ consistently from the Lyckholm specimens in that the sulcus always arises at the umbo. Further the fold and sulcus are much more strongly developed in the Norwegian, and also the Anticosti forms, than in typical *T. insularis*. These are certainly more important characters than actual size and overall shape in any comparison of these two species, for whilst the Russian specimens which have been examined usually show a strongly galeate dorsal valve, this does vary, with some specimens being much more transverse in outline and proportionally less domed as in typical *T. anticostiensis*. The Portrane valves are accordingly separated from *T. anticostiensis* on the weak initial sulcus, and its comparatively late development in the Irish shells (originating in a sample of 7 valves at a mean distance of 3·54 mm. (var. 1·23) from the umbo). This feature also readily distinguishes the Portrane shells from *T. woodlandensis*, which has a very strong sulcus, arising at the umbo and which is sharply defined throughout its length.

T. glabra differs from the Portrane shells in having a well developed fold, which is ridged according to Williams' diagnosis (1951 : 104). With respect to *T. glabra*,

it may be noted that the median and lateral ridges are probably the result of abrasion of the shell, being a feature of the internal mould, not of the exterior. Pl. 11, fig. 15 shows within the thickened Portrane shell three ridges in the fold corresponding to a median groove and the grooves of the adductors on the valve interior. The outer shell layer is also partially preserved on this specimen and is quite smooth ; with the removal of this it is clear that the three ridges would be completely exposed, as is seen on the internal moulds of *T. glabra*.

T. uniplicata has a much narrower hinge-line than the Portrane shells, according to Cooper & Kindle (1936 : 358) the " (valve) width a little more than twice width of hinge ". Otherwise there seems little difference in the shape of the valves, and in fold and sulcus development.

The Drummuck species of Reed, *T. asteroidea*, is characterized by the presence of a pronounced groove extending along the length of the ventral sulcus (1935 : 7). This is absent from the Portrane shells, although certainly present in some of the specimens from the Chair of Kildare Limestone, where *T. biplicata* Cooper & Kindle and forms resembling *T. insularis* also occur at the same horizon. Future work on the Kildare *Triplesia* may show the three to be simply variants of the same species.

From the material available, the Portrane shells resemble *T. insularis* very closely ; the Irish specimens are, however, inclined to be rather transverse, but the significance of this cannot be ascertained until type material of *T. insularis* has been re-assessed and more complete specimens obtained from Portrane.

Genus ***OXOPLECIA*** Wilson 1913

Oxoplecia cf. ***plicata*** (Wiman 1907)

(Pl. 11, figs. 5, 8, 11–14, 17)

1846 *Spirifer terebratuliformis* M'Coy : 38, pl. 3, fig. 26.
1861 *Orthis biforata* Schlotheim ; Baily : 11 (*pars*).
1880 *Orthis biforata* Schlotheim ; Baily : 82 (*pars*).
1895 *Orthis biforata* Schlotheim ; Sollas : 102 (*pars*).
1897 *Orthis biforata* Schlotheim ; Reed : 537.

Description. Dorsi-biconvex shells, somewhat wider than long, with a hinge-line about two-thirds of maximum valve width, and a pronounced dorsal fold and ventral sulcus. Ventral valves about one-third as deep as long, evenly convex in lateral profile ; anterior profile with rather flattish flanks divided by median sulcus, originating at about 2·5 mm. from the umbo. Interarea curved, apsacline, about one-sixth as long as wide and about one-eighth as long as the valve ; delthyrium closed by flat pseudodeltidium, with median fold only occasionally developed. Foramen apical, anterior to delthyrium. Dorsal valve about three-fifths as deep as long, strongly convex with maximum convexity umbonally in lateral profile ; anterior profile with strongly convex flanks separated by a flat topped fold, originating at about 2 mm. from the umbo. Concentric ornamentation of growth lines,

about 5 per mm.; radial ornamentation of stout rounded costae, together with costellae produced by both bifurcation and implantation. Fold and sulcus initially with 3 and 2 costae respectively ; on dorsal valve, wavelength of ribs at 7·5 mm. growth stage is about 1·3 mm., with total of 12–13 ribs developed at the 5 mm. growth stage.

Ventral interior with pedicle passage developed in the apex of a thick pseudodeltidium ; teeth strong, supported by receding dental lamellae. Muscle scars poorly preserved, a single valve showing a narrow elliptical adductor scar. Dorsal valve with cardinal process broad proximally, almost half the distance separating the tips of the posteriorly directed " brachiophores ", and deeply cleft with each prong fused more with the adjacent brachiophore than with the other prong. Hood not developed, commonly replaced by small pit. Shell substance thick posteriorly adductor scars and arcuate *vascula myaria* usually visible.

Figured Specimens	Length	Width
Ventral valve (BB.30337) . . .	9·2 mm.	10·9 mm.
Dorsal valve, broken anteriorly (BB.30338)	—	21·6 mm.
Also broken dorsal valves (BB.30339–41) and a ventral fragment (BB.30342) . .	—	—

Discussion. The sample of *Oxoplecia* obtained from the Portrane Limestone gives good evidence of the sorted nature of these deposits, as it shows the two opposing valves to be present in unequal quantities. This is a typical feature of disarticulated shells in sorted deposits, more especially in the case of valves which have markedly contrasted shape (as in the *Oxoplecia*), when the opposing valves behave differently on being subjected to current action, resulting from their different hydrodynamic properties.

The ratio of ventral to dorsal valves is practically the same at both principal localities from which a total of over a hundred valves was obtained ; at locality 1 the ventral valves formed 12·5% of the total, and at locality 2 they formed 14% of the total.

Although specimens of the genus are moderately abundant, they are almost invariably broken, to such a degree that sufficient data are not available for an analysis of shell shape. The most useful criteria for identification of the species are found in the nature of the ornamentation, and in the very distinctive cardinal process. This differs from that of *Oxoplecia multicostellata*, *Triplesia extans*, *Triplesia ortoni* and most members of the superfamily, in possessing a groove instead of a ridge at the proximal end of the cardinal process (cf. *Triplesia* cf. *insularis*, Pl. 11, fig. 9). The only other triplesiaceid known to have this type of cardinal process is *O. plicata* from the Leptaena Limestone of Sweden ; it may, however be present in other forms as the precise details of the cardinal process are unknown for the majority of triplesiaceid species.

The development of 2 initial costae in the sulcus and 3 on the fold distinguishes the Portrane form from most *Oxoplecia* species except for *O. subborealis* (Davidson 1883) emend. Williams 1962 ; *O. platystrophoides* and *O. costata* Cooper 1930 ; *O. abnormis*,

O. gibbosa and *O. parva* Cooper 1956 ; *O. perfecta* Cooper & Kindle 1936, and *O. plicata* (Wiman 1907) *non* Cooper 1956.

Twenty-nine Portrane dorsal valves have a mean rib wavelength of 1·28 mm. (var. 0·175) at the 7·5 mm. growth stage ; a comparison with Williams' data for *O. subborealis* (1962 : 153) reveals no significant difference. However, the number of initial costae on the fold is variable in the Girvan forms, which show both bicostate and tricostate patterns. Williams' Craighead sample is closer to the Portrane shells in this feature than the Balclatchie sample, having a proportion of tricostate : bicostate shells of 6 : 4. A 2×2 test indicates that the difference from the Portrane proportion (53 : 1) is significant (P=·001). A further difference in the rib pattern is that, unlike *O. subborealis*, costellae are developed from both the first and second costae away from the fold on all valves complete enough to show this feature (23 and 21 respectively), the costae being either external or internal. The concentric ornament is finer too, with a mode of 5 per mm. instead of 8 as on the Girvan shells.

In *O. platystrophoides*, the two initial costae of the sulcus branch at 3 mm. to produce 4 ribs by the 4 mm. growth stage, where the sulcus develops ; 3 is the maximum number to occur in any Portrane valve. Although Cooper (1930 : 278) did not indicate the number of specimens examined, he made it clear that, unlike the Portrane shells, there are 2 primary costae on the dorsal fold, with the possibility of a third intercalated between them. In the other Percé form, *O. costata*, the ribs do not arise at the umbo, but much later (at 0·6 mm. in Cooper's fig. 4 on pl. 2) as in *O. mutabilis* Whittington & Williams (1955 : 411). *O. costata* is also characterised by 4 ribs being present in the sulcus.

The narrowly and transversely elliptical outline of *O. abnormis* serves to differentiate it from any other Chazyan form (Cooper 1956 : 539), and this also applies in the case of the Portrane shells. According to Cooper (1956 : 543), *O. gibbosa* has either 3 or 4 ribs on the fold, but the three figured specimens (pl. 102, A) all show 4 at the 5 mm. growth stage. For a 2×2 test comparing the proportion of specimens bearing 3 ribs with those bearing 4 or more (0 : 3 and 52 : 9 for *O. gibbosa* and *O.* cf. *plicata* respectively) P=0·053, showing no significance with this sample. *O. gibbosa* may be distinguished from the Portrane shells by the smooth valve surface for the first 3 mm. of growth, and the poorly developed nature of the ribs on the flanks. *O. parva* differs from *O.* cf. *plicata* also in its smooth umbonal region ; in the subdued nature of the ribs and their common absence on parts of the shell ; in the late development of the fold and sulcus ; and probably also in a larger number of ribs on the flanks.

From the morphology of the exterior, *O. plicata* and *O. perfecta* are the most closely allied forms to the Portrane species ; the character of the cardinal process is not however known for *O. perfecta*. Slight variations in the ribbing are to be found, but good samples of both the Swedish and the Canadian shells need to be examined before their true systematic value can be assessed.

O. perfecta differs from the Swedish and Irish shells in possessing a strongly incurved ventral umbo. The ribs of the figured specimen of *O. perfecta* (Cooper &

Kindle, pl. 51, figs. 25–29) are less prominent than in *O.* cf. *plicata*, but this may be due in part to the preservation ; the left flank of the dorsal valve has 10 ribs at the margin, 7 on the fold, ? on the right flank, the specimen being 16·3 mm. long. A Portrane dorsal valve of length 16·4 mm. has 8, 9 on the left and right flanks respectively, and 6 on the fold. The fold of the Percé shell shows 5 ribs at the 10 mm. growth stage ; if this is the modal value for that species, it may prove to be significantly different to the Portrane shells whose mode is 3, although 5 ribs do occur (see below).

The Portrane shells resemble the Swedish *O. plicata* in the wide, proximally divided cardinal process, the absence of a cardinal process hood, and the general lack of a median fold on the pseudodeltidium. The ventral valve figured by Wiman (1907, pl. 2, fig. 14) has the umbo disposed in a similar manner, and a rib count of 7 on each flank and 2 in the sulcus as in the Portrane shells. The dorsal valve (pl. 2, fig. 13) shows a rib wavelength of 1·3 mm., but differs from the Portrane valves in having 7 and 9 ribs on the flanks and 6 on the fold at the 5 mm. growth stage, the total of 22 being well above the range of the Portrane shells. This difference between the dorsal and ventral valves figured by Wiman suggests that the variation in the Swedish shells may be much greater than in the Portrane shells. Until a sample of the Swedish shells is obtained this variation cannot be further assessed ; but it is quite clear that the Portrane shells are very closely related to, if not conspecific with, *Oxoplecia plicata*.

The following statistical data is included : —

Origin of dorsal fold (m). n=22 ; $\bar{m}$ (var. m)=2·15 mm. (0·13).

Origin of ventral sulcus (m). n=11 ; $\bar{m}$ (var. m)=2·55 mm. (0·341).

Width of cardinal process (x) (measured along an imaginary line joining the tips of the brachiophores) : distance between tips of brachiophores (y). n=14 ; $\bar{x}$ (var. x) =2·16 mm. (0·103) ; $\bar{y}$ (var. y)=4·86 mm. (0·71) ; r=0·8112 ; a (var. a)=2·63 (0·197).

Concentric ornamentation. 4–7 growth lines per mm. on 2, 6, 3, 1 specimens respectively.

Radial ornamentation in the ventral sulcus. (a) 12/12 specimens show 2 initial costae ; (b) at the 3 mm. growth stage, 2, 3 ribs occur on 10, 1 valves respectively ; at 5 mm. on 7, 2 valves ; and at 10 mm. on 2, 1 valves.

Radial ornamentation on dorsal fold. (a) 2, 3 initial costae shown by 1, 53 valves respectively ; (b) at the 3 mm. growth stage, 3, 4, 5 ribs shown by 56, 5, 0 valves ; at 5 mm., on 52, 7, 2 valves ; and at 10 mm. on 14, 7, 2 valves.

Total ribs on dorsal valves at the 5 mm. growth stage ; 11–16 ribs on 4, 5, 5, 2, 0, 2 valves.

Oxoplecia cooperi nom. nov.

1956. *Oxoplecia plicata* Cooper : 555, pl. 104, E, figs. 25–31.

The new name is erected to replace *Oxoplecia plicata* Cooper, which is pre-occupied by *Oxoplecia plicata* (Wiman 1907 : 12, 13).

Genus *STREPTIS* Davidson 1881

Streptis monilifera (M'Coy)

(Pl. 11, figs. 3, 4)

1846. *Producta monilifera* M'Coy : 25, pl. 3, fig. 3.

Description. Dorsi-biconvex, uniplicate shells, with a ventral valve slightly longer than wide, due to the sulcus extending anteriorly in the form of a tongue ; cardinal angles roundedly obtuse, with maximum shell width slightly anterior to the hinge-line. Sulcus strong, rather " U "-shaped in profile, originating at 2·5 mm. anterior to the umbo in the figured specimen. Ornamentation on this valve consisting of nine strong concentric lamellae (frill bases), with superimposed radial costellae. Frill bases with wavelength of 0·9 mm., measured in the sulcus medianly, anterior to the 3 mm. growth stage ; on the immediate flanks the wavelength for the same lamellae is only 0·5 mm., adjacent lamellae becoming closer when traced to the posterior margin. Dorsal valve strongly convex with a low median fold, complementary to the ventral sulcus, which originates at 2·2 mm. from the umbo in the figured specimen ; shell broken, but is apparently somewhat wider than long. This shell shows nine frill bases, five being developed at a distance of 3·1 mm. from the umbo, with a wavelength of 0·55 mm. measured medianly immediately posterior to this growth stage.

Interiors of both ventral and dorsal valves obscured by silica, except for the hinge region of the latter, which shows a small, forked cardinal process with a small hood developed ; parts of the " brachiophores " visible laterally.

Discussion. This species is of rare occurrence in the Portrane Limestone, only one ventral (BB.30343), 7 mm. long and 6·7 mm. wide, and one dorsal valve (BB.30344) being recovered, together with a ventral fragment ; adhering silica prevents an examination of the interiors, except for the features along the dorsal hinge-line.

The ventral fragment is part of a sulcus whose posterior side must certainly be over 3 mm. from the umbo. The style of this sulcus is similar to that of the complete valve ; the wavelength of the frill bases is 0·8 mm. ; and 5 radial ribs are present in a 2 mm. length, measured at right angles to the direction of growth.

Sufficient data are available to show that these shells belong to the species *S. monilifera*, topotype material of which was recently redescribed biometrically by Wright (1960). The plication on the Portrane dorsal valve is clearly present at a distance of 2·5 mm. from the umbo ; just perceptible at 2·2 mm. (designated as the origin in the above description) ; but not seen at the 1·9 mm. frill base. Posterior to this, the valve is badly abraded, but it is quite certain from the degree of development of the plication at the 2·2 mm. stage that it is absent from earlier stages. In *S. altosinuata* Holtedahl, a Llandovery form which is close to *S. monilifera*, the plication is already well developed at the 2 mm. growth stage. The position of origin of the plication is in fact one of the specific differences between the two forms, being at 1·16 mm. (var. 0·043) for a sample of 40 *S. altosinuata*, and at 2·0 mm. (var. 0·065) for 24 *S. monilifera* (Wright 1960 : 269).

The wavelength of the frill bases on the Portrane dorsal valve also resembles that of the Kildare form. In the latter case the measurement was taken anterior to the 3 mm. growth stage ; accordingly precise comparison is not possible as the shell of the Portrane valve is missing medianly anterior to the 3·1 mm. position. Posterior to this, however, the wavelength is 0·55 mm., which compares closely with the mean of 0·52 mm. obtained for the Kildare shells (Wright 1960 : 271), in spite of the slightly different position of measurement.

Although the development of five frill bases by the 3·1 mm. growth stage of the dorsal valve may occur in either *S. monilifera* or *S. altosinuata*, this is the modal number for the former, compared with a mode of seven for the latter (Wright, Tables 2 and 3).

The presence of five radial ribs in 2 mm. on the ventral fragment cannot be closely compared with the Kildare material as the exact position of the fragment relative to the umbo is not known and Wright's figures (Table 1B) are given for the dorsal valve only. However, these Kildare data show that the occurrence of 4–6 ribs is more typical of *S. monilifera* than *S. altosinuata*.

Thus the details of the ornamentation, together with the strong overall resemblance between the Portrane and Kildare shells (particularly in the dorsal valves, see Wright 1960, pl. 1, fig. 17), clearly indicate the two forms to be conspecific.

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